Innovation in pharma companies: an investigation of R&D and external knowledge acquisition

Thesis

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Innovation in pharma companies: an investigation of R&D and external knowledge acquisition

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Abstract

The study builds on the theoretical assumptions that extramural knowledge plays a crucial role for innovation and firms have the ability to acquire such knowledge.

Inspired by the rise of biotechnology and big pharma's increasing reliance on internal and external R&D, the *first aim* of this study is to obtain an in-depth understanding of the distinctive effects the different knowledge acquisition strategies, R&D and collaborations, have on big pharma's innovation and capability building. The *second aim* recognises a gap in the literature with regards to understanding the practice of absorptive capacity and, building on Zahra and George's (2002) framework, seeks to investigate the key processes that enable a firm to acquire, assimilate, transform and exploit extramural knowledge.

The first aim was achieved through carrying out: a multiple case study on three big pharma companies and a case study on two large scale collaborations (one of which resulted in an acquisition) entered by one of the three big pharma companies to access the field of monoclonal antibodies. The latter provided also the primary context to achieve the second aim.

The investigation into the effects of R&D and collaborations firstly showed that due to the large scope of science and technology that has emerged over the last decade, big pharma has found itself unable to competitively enter into all the relevant areas. Hence, big pharma has increasingly used collaborations to reap small biotech's inventions. Given that big pharma is primarily responsible for the later stages of development, the key role of big pharma's R&D is increasingly becoming to identify, evaluate and develop externally invented candidate drugs; a role highly dependent on R&D investments. Despite their importance for obtaining inventions, the study provided evidence that collaborations have limited impacts on big pharma's learning and capability building.

The new emphasis of big pharma's R&D resembles Cohen and Levinthal's (1990) definition of absorptive capacity and is in line with their theory in that it requires investments in R&D. However, as the compounds are accessed through collaborations, the new emphasis of R&D also seems to fit the realms of relative absorptive capacity. Hence, despite fitting both types of absorptive capacity, the finding that this new emphasis has limited impacts on learning and capability building clearly stands in sharp contrast to both the theories, providing an indication that a new face of absorptive capacity was unveiled. This thesis argues that the new emphasis is a result of a division of labour taking place between big pharma and small biotechs (Arora and Gambardella, 1994).

Though collaborations have limited impacts on capability building, the specific investigation into the practise of absorptive (second aim) found that prior knowledge, champions on both sides of the collaborations, project review meetings and supportive culture have some effect on knowledge *acquisition*. With regards to the other dimensions, *assimilation* was seen dependent on internal collaborations between the recently acquired firm and new therapy areas, *transformation* was obtained by combining big pharma's ability to define niches in the market with the small biotech firms' more specific knowledge, and *exploitation* was found to require some pre-set measures to evaluate the potential of the new knowledge.

In loving memory of my father

Acknowledgement

There are certainly many to whom I owe a big thank for making this PhD thesis a reality.

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Table of Contents

Table of Contents....1

List of Tables....5

List of Figures....6

Chapter 1: Introduction to Research....7

1.1 Empirical context....9

1.1.1 Rational design and biotechnology and the adoption by industry....9

1.1.2 The impacts of the new advances on drug innovation....15

1.1.3 Division of innovative labour....17

1.1.4 R&D inefficiency....19

1.2 Theoretical motivation and focus for the research....21

1.2.1 Theoretical motivation....21

1.3 Scoping the boundaries of the research....23

1.4 Thesis outline....24

Chapter 2: Review of literature....27

2.1 Introduction....27

2.2 Knowledge and innovation....28

2.3 R&D, innovation and capacity building....30

2.3.1 Critical review of absorptive capacity....32

2.3.1.1 Theory of and evidence for absorptive capacity....32

2.3.1.2 Critical review of key concepts....38

2.3.2 Absorptive capacity – a dynamic capability....44

2.4 Collaborations, innovation and capacity building....46

2.4.1 Firm-firm collaborations....50

2.4.2 University-industry collaborations....56

2.5 Complementarity between the knowledge acquisition strategies....59

2.5.1 Complementarity between internal and external R&D....59

2.5.2 Division of innovative labour....65

2.6 What is the practice of absorptive capacity?....67

2.7 Introduction to Zahra and George's framework and empirical work....68

2.7.1 Practice of absorptive capacity....70

2.8 Research questions....73

Chapter 3: Methodology 79

3.1 Research questions 79

3.2 Epistemological stance 80

3.2.1 Epistemological views 81

3.2.2 Rationale for choosing Empirical Realism 83

3.3 Choice of research method: multiple case studies 84

3.3.1 Rationale for choosing case study methodology and its research methods 84

3.3.2 Applying a case study methodology 89

3.3.3 Limitations of case studies 90

3.4 The units of analysis 91

3.5 The choice of empirical sample 93

3.5.1 Negotiation of access 95

3.6 Methods of investigation 95

3.6.1 Archival and data analysis 96

3.6.2 Semi-structured interviews 100

3.7 Approach to data analysis 104

3.7.1 Within-case analysis 104

3.7.2 Cross-case analysis 106

3.8 Case study quality 107

3.9 Summary and presentation of findings 109

Chapter 4: The importance played by R&D and collaboration for innovation and capability building - a quantitative analysis 111

4.1 Introduction 111

4.2 Quantitative profiles of selected firms 111

4.2.1 Pfizer 113

4.2.2 AstraZeneca 130

4.2.3 GSK 143

4.3 Cross-case analysis 153

Chapter 5: Cross-case interviews 157

5.1 Introduction 157

5.2 The importance of R&D and collaboration for innovation and capability building 157

5.2.1 Interviewees' perceptions of the distinctive importance R&D and collaborations have for innovation and capability building. 158

5.2.2 When does big pharma prefer to collaborate? 165

5.2.3 Types of collaborations 167

5.2.4 The value of the different types of collaborations....171
5.2.5 Collaborations' impact on innovative capabilities....172
5.2.6 When do firms seek to carry out acquisitions in preference to forming collaborations?....183
5.2.7 Why has R&D failed to deliver?....185
5.2.8 Changing role of R&D....190
5.2.9 Dynamic relationship between R&D and collaborations....196
5.3 Key processes enabling a firm to acquire, assimilate, transform and exploit knowledge....198
5.3.1 Identification and evaluation of potential collaborators....199
5.3.2 Acquisition of knowledge....205
5.3.3 Assimilation of knowledge....207
5.3.4 Transformation of knowledge....209
5.3.5 Exploitation of knowledge....210
5.4 Summary of findings....212

Chapter 6: Case study....215
6.1 Introduction....215
6.2 Background for entering into large scale collaborations to move into MAbs....216
6.3 Key processes involved in identifying and evaluating firms and formulation of deals....218
6.4 Nature of the deals....226
6.4.1 What were the underlying reasons for entering into such different deals?....228
6.4.2 Aims, structure and implications of collaborations....231
6.5 Effects of the collaborations....236
6.5.1 The respective effects of the collaborations....237
6.5.2 Effects of acquisitions and the underpinning reasons for AZ acquiring CAT and MedImmune....244
6.6 Success factors....257
6.7 Key processes behind the knowledge transfer....264
6.7.1 Acquisition of knowledge....265
6.7.2 Assimilation....267
6.7.3 Transformation....268
6.7.4 Exploitation....268
6.8 Summary....268

Chapter 7: Analysis and discussion 271

7.1 Introduction 271

7.2 R&D and the importance of identifying and evaluating collaborators 272

7.2.1 Evidence for the increasing importance of collaborations 275

7.2.2 Implication for theory: a new face of absorptive capacity and its importance for complementarity 277

7.3 Collaborations' limited impacts on capability building 280

7.3.1 Large scale and key collaboration criteria 281

7.3.2 Knowledge acquisition – learning – capability building 284

7.4 Conclusion 291

Chapter 8: Conclusion 293

Appendices: 301

Appendix A: M&A activity of Pfizer, GSK, AstraZeneca and Merck 301

Appendix B: Interviewees 305

Appendix C: Interview guide 307

List of references: 315

List of Tables

Table 3.1: Strength and weaknesses associated with suitable research methods 89

Table 3.2: Overview of the research methods and type of data to be collected for the research questions.....96

Table 3.3: Measures to test case study quality 107

Table 4.1: R&D expenditure related to collaborations in the period 2004-2009 – Pfizer*.....118

Table 4.2: Top pharma firms in period 1980 - 2008.....119

Table 4.3: R&D expenditure related to acquisitions in the period 2004-2008 – Pfizer* 121

Table 4.4: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – Pfizer 125

Table 4.5: R&D expenditure related to collaborations in the period 2001-2009 – AstraZeneca.....133

Table 4.6: AstraZeneca's collaboration history.....133

Table 4.7: R&D expenditure related to acquisitions in the period 2001-2009 – Astrazeneca.....136

Table 4.8: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – Astrazeneca.....139

Table 4.9: R&D expenditure related to collaborations in the period 2001-2009 – GSK 146

Table 4.10: R&D expenditure related to acquisitions in the period 2001-2009 – GSK 147

Table 4.11: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – GSK 150

Table 5.1: Key processes for knowledge acquisition, assimilation, transformation and exploitation.....211

Table 6.1 The principal terms underlying the Abgenix and CAT agreements.....227

List of Figures

Figure 1.1 12
Figure 1.2 12
Figure 1.3 13
Figure 1.4 13
Figure 1.5 15
Figure 1.6 17
Figure 1.7 19
Figure 1.8 20
Figure 1.9 20
Figure 3.1 92
Figure 3.2 92
Figure 4.1 115
Figure 4.2 115
Figure 4.3 120
Figure 4.4 122
Figure 4.5 126
Figure 4.6 127
Figure 4.7 128
Figure 4.8 128
Figure 4.9 131
Figure 4.10 132
Figure 4.11 135
Figure 4.12 137
Figure 4.13 140
Figure 4.14 141
Figure 4.15 141
Figure 4.16 145
Figure 4.17 145
Figure 4.18 147
Figure 4.19 148
Figure 4.20 151
Figure 4.21 152

Chapter 1:

Introduction to Research

The research builds on the premises that extramural knowledge plays a crucial role for innovation and that firms have the ability to acquire knowledge from external sources and, as such, the motivating question arises: *how do firms acquire the knowledge and capabilities to move into new areas?*

Biotechnology is a clear example of a technology that has emerged and provided techniques for drug innovation, which are fundamentally different from the traditional chemistry-based approach to drug innovation. With the rise of biotechnology, much of the extant knowledge in biotechnology and the ability to create new knowledge in this field lie outside the traditional pharmaceutical firms' expertise. Theoretically, firms have a choice between investing in their R&D or carrying out collaborations or M&As to acquire knowledge in this new area. In fact, the large pharmaceutical firms are reported, both in academic papers and in the press, to have exponentially increased their R&D, since the introduction of biotechnology, in addition to entering into an increasing number of inter-organisational collaborations (with dedicated biotechnology firms as well as universities with specific capabilities in this area) and acquiring niche biotech firms (Arora and Gambardella, 1990; Powell *et al.,* 1996; Roijakkers and Hagedoorn, 2006). However, despite the exponential increase of its investments in internal and external R&D, 'big pharma' is currently experiencing a severe fall in drug innovation. Interestingly, the R&D inefficiency (i.e. the lack of new drugs coming out of very large R&D expenditures) is regarded as so severe that the CEO's of several big pharmaceutical firms recently

announced at the Financial Times Global Pharmaceutical & Biotechnology conference 2009 the cutting of their firms' R&D expenditure. Given that these firms are the largest firms in one of the world's most research-intensive industries, the decision to cut their R&D clearly represents a momentous change.

The fact that big pharma, in spite of their efforts of investing in R&D and carrying out collaborations and M&A's, is experiencing a severe fall in innovation provides a reverse picture than theoretically expected and, as such, 'big pharma' provides an intriguing context for investigating the research's motivating question of how firms acquire the knowledge and capability to enter into new areas.

In order to obtain a wider understanding of the empirical setting in which big pharma operates, section 1.1 seeks to provide a deeper insight into the nature of the scientific and technological advances that have emerged over the last decades, their impacts on drug innovations and the industry structure, increase in firms' R&D and use of collaborations as well as the observed R&D inefficiency taking place in the pharmaceutical industry. Importantly, by introducing the innovation process, this section introduces the relevant terminology that the research will refer to.

Whilst section 1.1 provides a deeper understanding of the empirical setting, section 1.2 seeks to evaluate the fact that big pharma, in spite of its efforts, is currently experiencing an R&D inefficiency in the light of the most central theoretical concept addressing the importance of acquiring knowledge for innovation, i.e. absorptive capacity (Cohen and Levinthal, 1989, 1990, 1994). By drawing on this literature, this section seeks to present more clearly the theoretical motivation behind this research. Introducing the theoretical aims of the research, this section also seeks to define the theoretical boundaries of the research. The chapter ends with an overview of the thesis in section 1.3.

1.1 Empirical context

The pharmaceutical industry started in the 1970s to benefit more directly from the high public funding in health related research that had followed in the post-war years. Whilst section 1.1.1 starts introducing the nature of the key advances that emerged from this research, i.e. the rational drug design and biotechnology, and the degree to which the new advances were adopted by the industry, section 1.1.2 provides a deeper insight into the specific impacts the new advances have had on the drug discovery process. The subsequent sections 1.1.3 and 1.1.4, on the other hand, focus primarily on the industry, by respectively introducing a new industry structure emerging in the drug industry as well as providing evidence for the current R&D inefficiency that is taking place in the industry.

1.1.1 Rational design and biotechnology and the adoption by industry

The developments of the rational drug design and biotechnology and the subsequent adoption of industry are presented in distinctive sections below.

Rational drug design

From the mid 1970s, substantial advances in physiology, pharmacology, enzymology and cell biology led to an increased understanding of the 'mechanisms' of existing drugs, and the biochemical and molecular roots of many diseases. This improved understanding paved the way for the development of the techniques of 'guided search' and 'rational drug design', whereby new biological knowledge was directly applied to the design of new compounds as well as to the ways in which they were screened. This scientific approach to designing new compounds stands in clear contrast to the previous knowledge regime, i.e. random search regime, where the process of designing new compounds drew primarily on the individual chemists' skills and intuitions, and little codified knowledge. In fact, serendipity played a key role in the random search design, as the mechanisms of drugs

were not fully understood (Malerba and Orsenigo, 2001; Pisano, 2002; Ramirez and Tylecote, 1999; Gambardella, 1995).

New techniques were not universally exploited by the industry. Whilst large American pharmaceutical firms are reported pioneering the new technology (Malerba and Orsenigo, 2002), Gambardella (1995) shows the adoption of the new techniques were less frequently adopted by small firms. This was especially the case for those firms situated farthest away from centres of public research and those that were most successful with the techniques of the random drug design.

Biotechnology

The transition to the techniques of the rational drug design was in mid-course (late 1970s), "[...] when molecular genetics and rDNA technology [was introduced and] opened an entirely new frontier for pharmaceutical innovation" (Malerba and Orsenigo, 2001: 6).

Advances in genetic engineering and molecular genetics evolved as a new branch of new knowledge, laying the basis for the 'biotechnology industry' (Gambardella, 1995). rDNA was the first technique that exploited the new advances, soon to be followed by a constellation of inter-dependent techniques (Pisano, 2002). Drews (2001) provides a deeper insight into how the development of the biotechnology industry took place, holding that every breakthrough related to healthcare was exploited by new firms. The result of this was a growth in firms specialising in a range of new techniques, i.e. "*monoclonal antibodies, antisense molecules, ribozymes, gene therapy, cell therapy, natural products, drug delivery systems, genomics (gene mapping, sequencing, expression), pharmacogenomics (the assessment of drug responses on the basis of genetic dispositions), various forms of combinatorial chemistry, developmental biology, HTS* [high throughput screening] *techniques and bioinformatics*" (p.21). Pisano (2002) shows that the techniques

had significant effects on drug discovery process, providing specific methods for searching for, synthesising and screening compounds. Biotechnology was generally perceived as a 'revolution' (Nightingale and Martin, 2004)

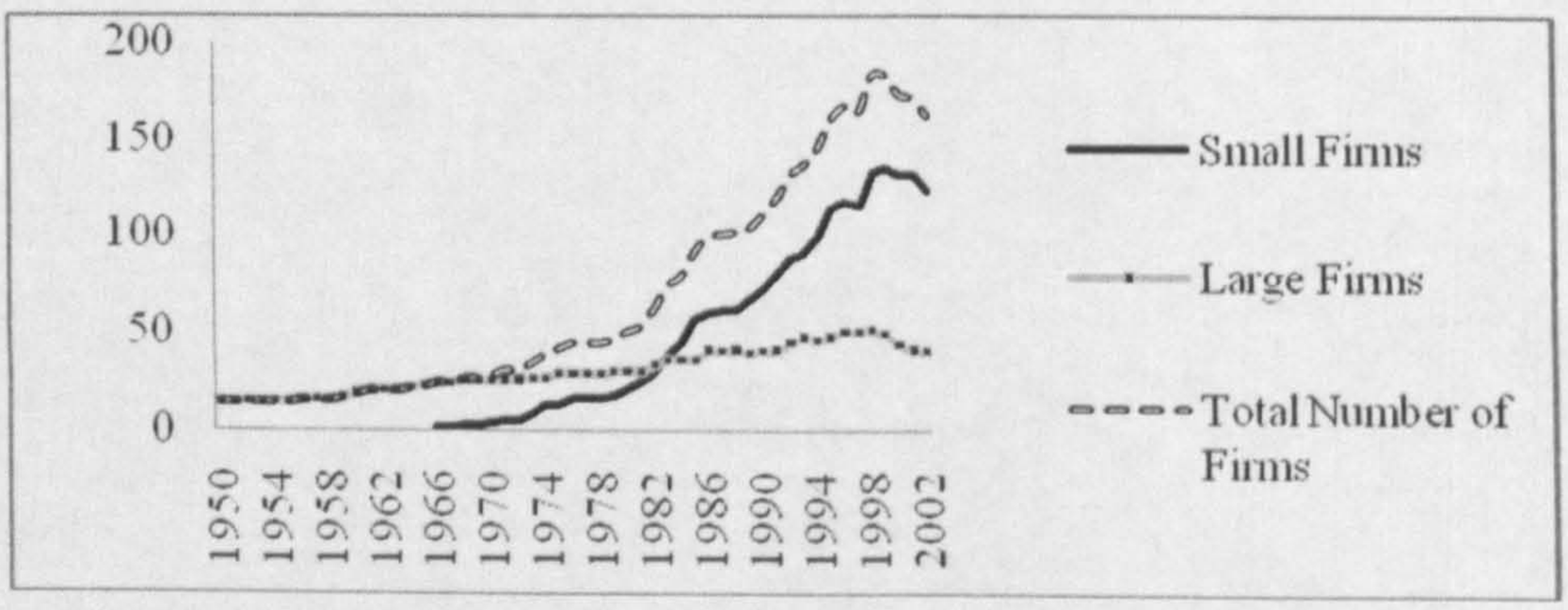
The great majority of firms seeking to exploit the new breakthrough advances were university spin offs. As such, whilst the initial advances were a result of publicly funded university research, the university spin-offs used their capabilities in the various areas to develop this knowledge into applied knowledge (Malerba and Orsenigo, 2002).

Backed by availability of venture capital as well as a favourable climate for patenting, particularly following the new American appropriation rules introduced by the Bayh-Dole Act (1980), which provides that universities and small businesses can protect their intellectual property, by patenting results stemming from research sponsored by the National Institute of Health, and to grant licences to drug firms, the entry rate of small firms is reported to have soared over the 1980s.

Analysing the entry rate of small firms in the period (classified as firms with less than 500 employees), using the COMPUSTAT Database, Demirel (2008) provides evidence for the soaring entry rates of these small firms. As seen in Figure 1.1, the entry of new firms increased around seven times in the period 1978-1998. Furthermore, combining the COMPUSTAT Database with the NBER patent and citations database, Demirel (2008) further illustrates the significant impacts these small firms had on industry innovation in the same period. Specifically, Figure 1.2 shows not only that the small firms' share in citations and patents rose from an insignificant level of 0-1% to 13% and 2% respectively in the late 1970s, when biotechnology started, but also that their shares in these measures of innovation have remained high and in fact increased substantially towards the end of the

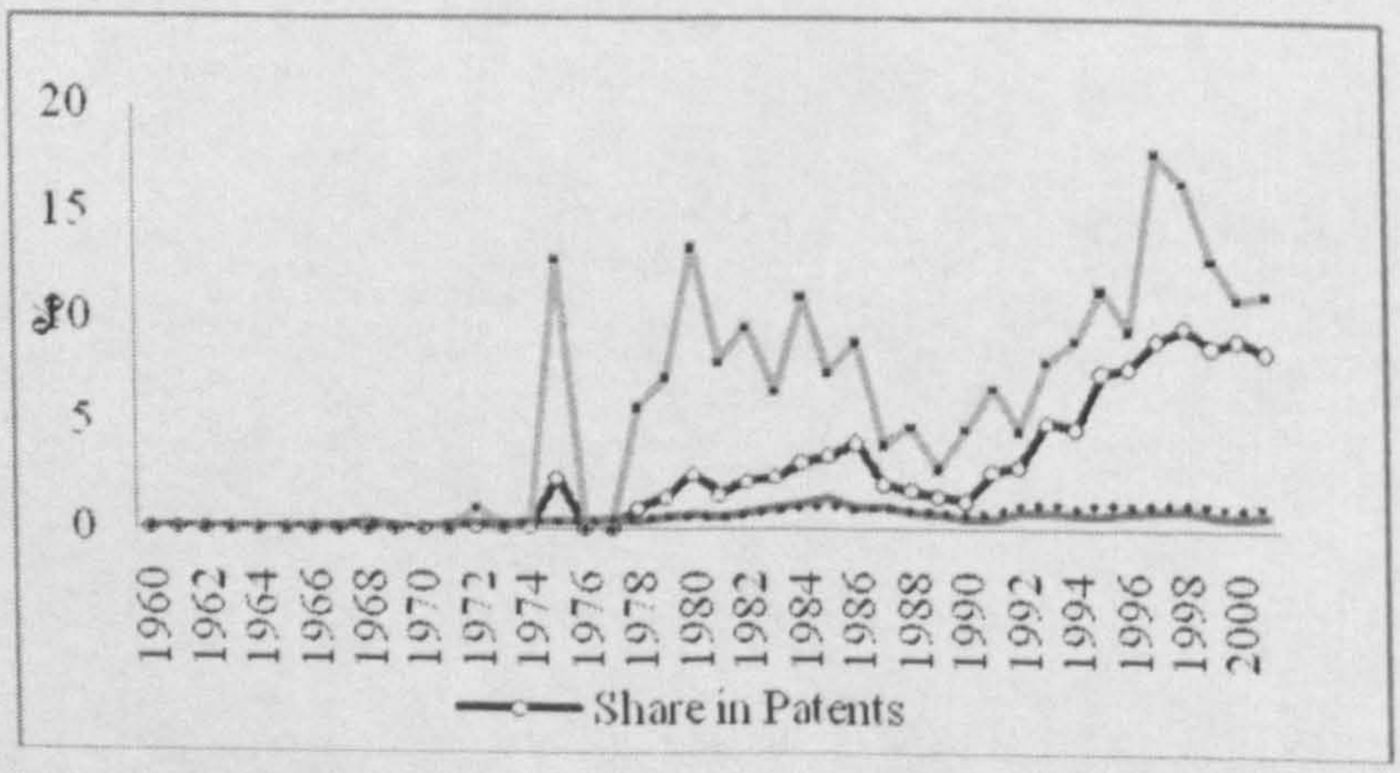
1990s. Additionally, this increase in innovation has taken place in a period where the small firms' shares in employment and revenues increased only slightly. The high impact of the small firms is further supported by the decline in the concentration of patents, as illustrated in Figure 1.3, suggesting that the patents were filed by a larger number of firms as opposed to only a few. This, coupled with the high concentration of the pharmaceutical industry, implies that relatively more patents were filed by smaller firms. Using the same database as above, i.e. the COMPUSTAT Database, Figure 1.4, on the other hand, provides insight into the small firms' R&D efforts, revealing a five-fold increase in their R&D expenditure in the period 1980-2003.

Figure 1.1: Number of Firms in the Pharmaceutical Industry



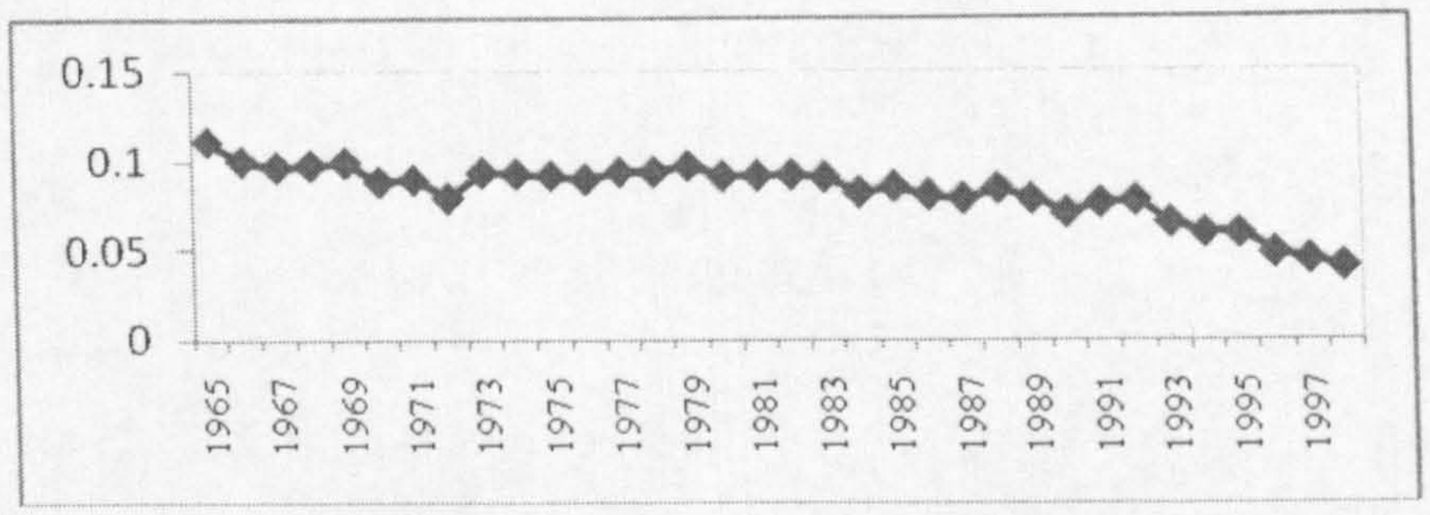
(Source: Demirel, 2008)

Figure 1.2: Share of Small Firms in Innovative Activities, Revenues and Employment



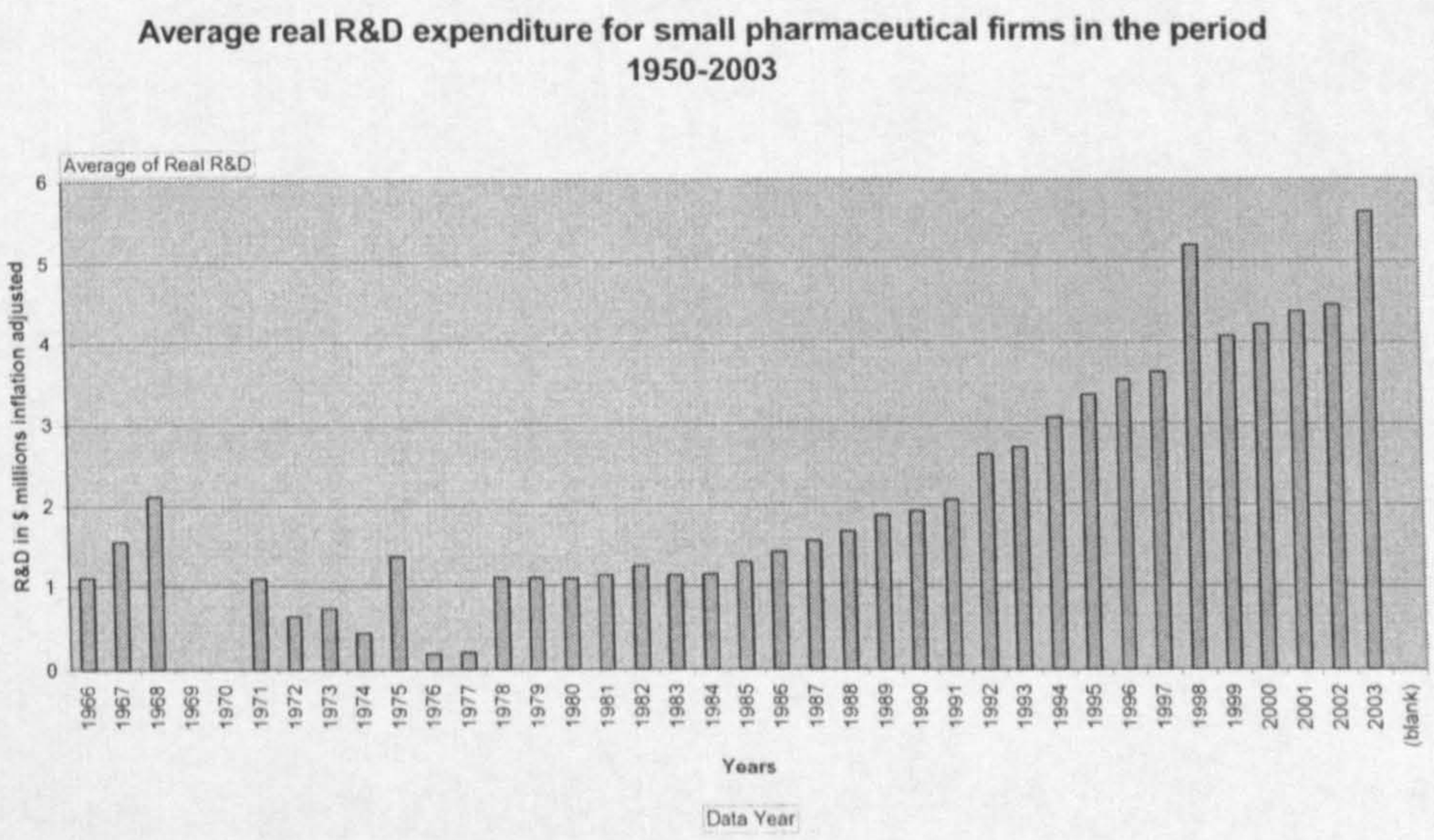
(Source: Demirel, 2008)

Figure 1.3: Concentration of Patents (measured by normalised Herfindahl index)



(Source: Demirel, 2008)

Figure 1.4:



Source: Author's calculations from COMPUSTAT Database.

Notes: Small firms are classified as those with less than 500 employees

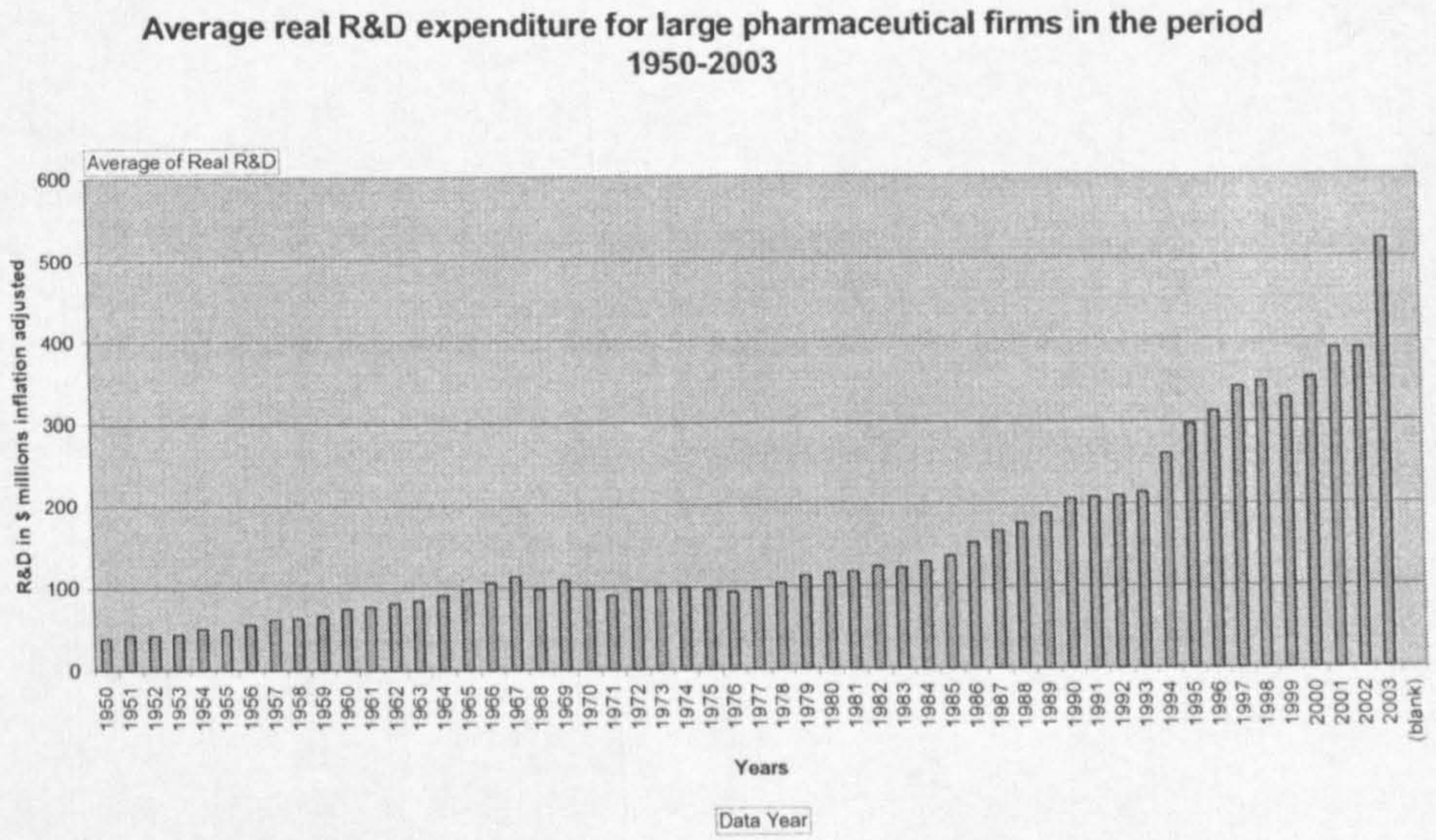
It is important to note that, despite the high entry rates of small biotechnology firms and their high impact on citations and patents over the 1980s, the market had at this time only seen a few biotechnology drugs. As such, although there was optimism towards the new biotechnology methods, there were also uncertainties around the extent they would deliver. This in addition to the fact that the large pharmaceutical firms had made big investments in the rational design techniques, and had drugs in their pipeline that built on this these, made the large firms await their involvement in biotechnology until late 1980s (Galambos and Sturchio, 1998). Shuker and Williams (2007), on the other hand, see Smithkline

Beecham's landmark agreement with Human Genome sciences in 1992 mark the turning point, which made the large pharmaceutical firms take a greater interest in the new biotechnology methods.

Given the high level of expertise in biotechnology found in universities as well as small biotechnology firms, the large pharmaceutical firms not only actively formed collaborations with universities and small biotechnology firms but also acquired specific niche biotechnology firms to enter into biotechnology (Gambardella and Arora, 1990). Although collaborations and acquisitions are reported as the key strategies for entering into biotechnology, Figure 1.5 also shows an exponential increase in the large pharmaceutical firms' R&D investments in over the 1990s.

Despite direct efforts to enter into biotechnology, it was soon apparent that the new knowledge base posed a clear challenge for the large, established pharmaceutical firms. Henderson *et al.* (1999) report the learning process as slow and painful. The reason for this was not only that the new knowledge base was very different from medicinal chemistry but also the sheer breadth of knowledge and skills represented by the new technologies (Pisano, 2002). According to Malerba and Orsenigo (2002), the embodiment of the new knowledge involved radical changes in the research procedures, implying a re-organisation of disciplinary boundaries within laboratories and sometimes also a divisional structure of the company. Interestingly, Henderson *et al.* (1999) report adaptation to the techniques of rational drug design as a discriminating factor between successful and unsuccessful firms. However, despite a troublesome start of entering into biotechnology, some of the key players achieved some success by mid 1990s (Galambos and Sturchio, 1998).

Figure 1.5:



Source: Author's calculations from COMPUSTAT Database.

Notes: Large firms are classified as those with more than 500 employees

1.1.2 The impacts of the new advances on drug innovation

The application of detailed scientific knowledge to the design and screening of new compounds, made possible with the techniques behind rational drug design, in addition to the range of technologies and techniques that emerged through the rise of biotechnology enabled a more "guided" search in the process of drug discovery, as they allowed the firms to build up a more systematic knowledge base, and hence, more systematic research capabilities than it had been possible before (Nightingale, 2000). Together, these scientific and technological advances have changed the methods of R&D. Pisano (2002) provides a deep insight into three inter-related processes, as presented below.

i) Search for therapeutic targets

The drug discovery starts with the search for therapeutic targets. As seen above, the advent of the rational drug design enabled scientists to design new compounds for specific targets on the basis of the biochemical pathways of diseases. Using the analogy of 'locks' and 'keys' respectively for targets and compounds, Pisano (2002) explains that advances in

scientific knowledge increased the understanding of the 'locks', making the screening more precise, whilst the more recent knowledge has improved the understanding of the 'keys'.

ii) Synthesis of therapeutic compounds

The second stage of the drug discovery is to synthesise therapeutic compounds. As seen above, there is now a range of new techniques which can create therapeutic substances.

- Recombinant DNA, which transfers genes from one organism to the cell of another. The most famous example is development of human insulin, marking the very beginning of biotechnology.
- Monoclonal antibodies (Mabs), a technique to produce highly pure antibodies by creating an immortal cell line which can produce a single antibody of a defined specificity (Pisano, 2002, p. 356).
- Genetherapy, which has as one of its goal to 'identify defective genes causing a specific disease and then fixing it by supplying with healthy copies of the missing or flawed genes' (p. 357).
- Combinatory chemistry, which provides an effective way of combining molecules.

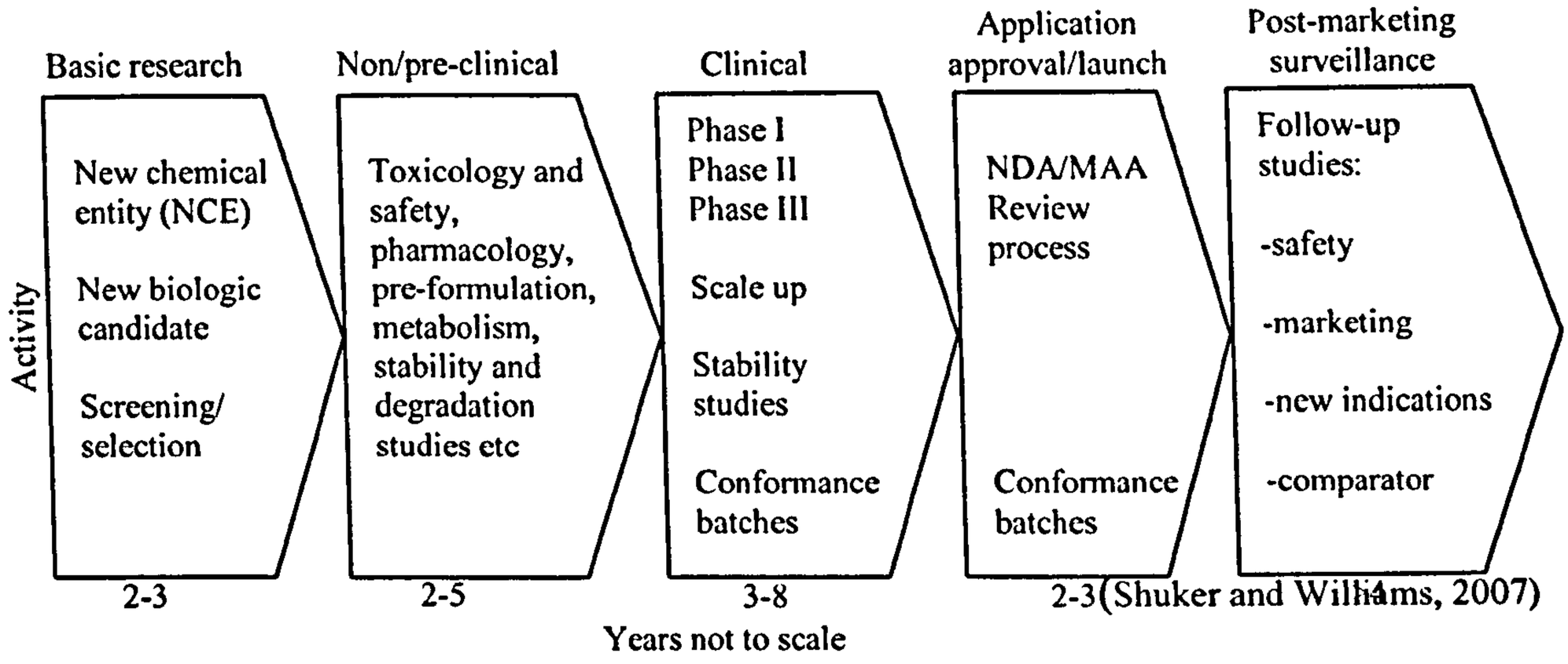
iii) Screening of therapeutic compounds with desired activity

The third stage of the drug discovery process involves screening the compounds with desired activity. High Throughput Screening (HTS) is an automated technology for testing a vast number of compounds against a large number of assays.

Comparing the above with Figure 1.6 illustrating R&D approval process in the pharmaceutical industry, the processes, i.e. search for, synthesis and screening of therapeutic compounds, comprise the basic research stage of the drug development. According to the figure, although the basic research phase is estimated to take 2-3 years, it

takes another 2-5 years carrying out specific studies, e.g. testing for toxicology, safety and pharmacology, before the therapeutic compound is ready to be tested in clinical trials. Whilst the clinical trials can last between 3-8 years, the application of approval takes about 2-3 years. As such, it can take a minimum of 9 years before the product can be launched. The post-marketing and surveillance is estimated to take up to four years.

Figure 1.6: the R&D approval process in the pharmaceutical industry



(Shuker and Williams, 2007)

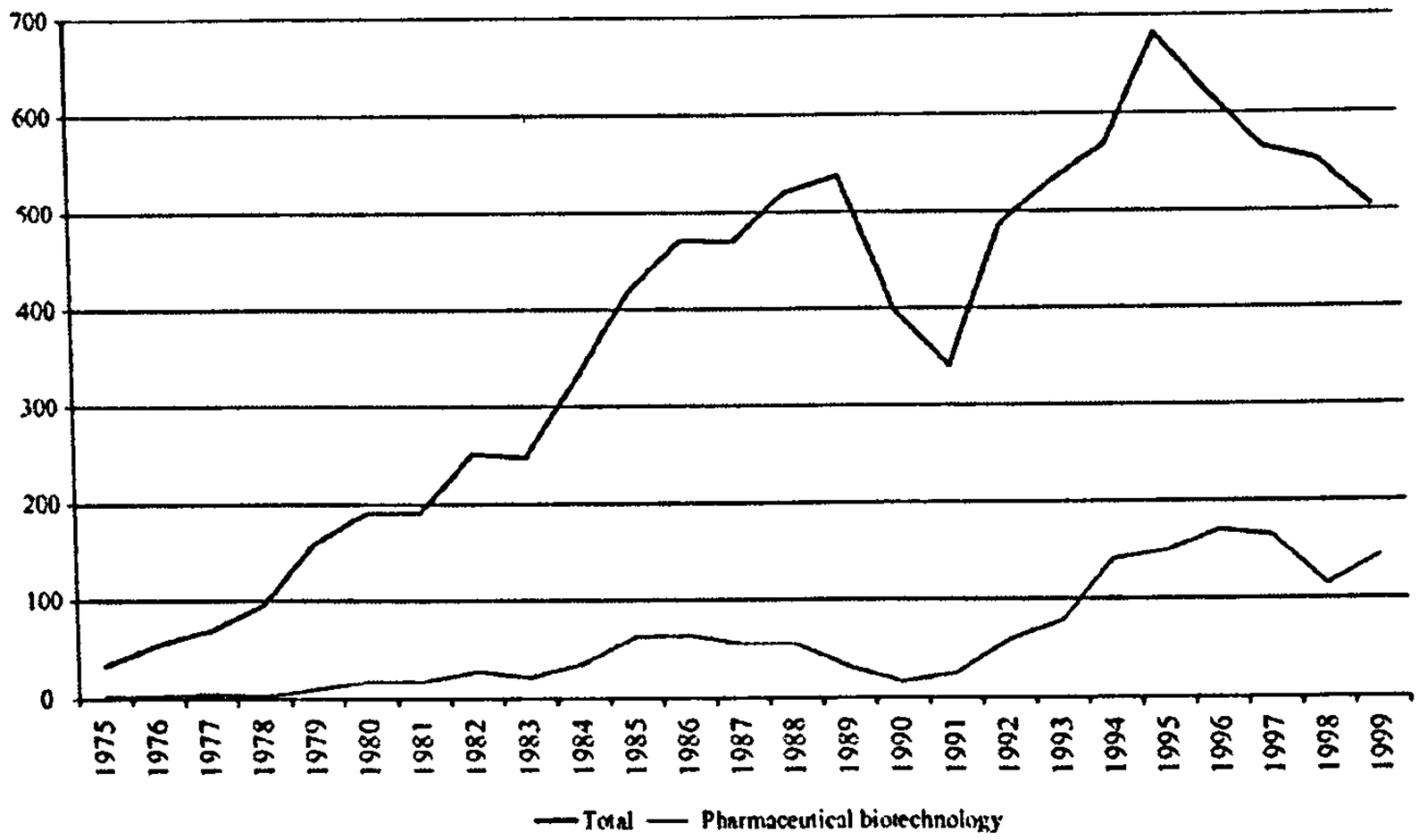
1.1.3 Division of innovative labour

As seen above, whilst the new advances emerged from publicly funded university research, the role of university spin-offs was to develop these advances into applied knowledge. Although innovative, the great majority of the small biotechnology firms never managed to develop into fully integrated drug producers, as they found themselves lacking capabilities in the later stages of the drug innovation process, i.e. clinical testing, product approval and marketing. Large pharmaceutical firms found themselves in the opposite situation, i.e. whilst experiencing difficulty adopting the new biotechnology methods, they had developed strong capabilities in the later stages of the innovation process. Indeed, these complimentary capabilities were among the reasons leading to a dense network of collaborations between large and small firms, creating a stronger division of labour in the pharmaceutical/biotechnology industry, where, on the one side, small biotechnology firms

together with academia were specialising on drug discovery and large pharmaceutical firms on development and marketing of drugs on the other side (Arora and Gambardella, 1994b).

Figure 1.7 illustrates the increasing number of R&D partnerships in the pharmaceutical firms over the period 1975-1999. The sharp increase in partnership over the 1990s coincides the large pharmaceutical firms' more pronounced strategy of entering into biotechnology. Furthermore, seeking to identify the structure of inter-firm R&D networks, Roijakkers and Hagedoorn (2006) find an interesting pattern, i.e. whilst "small, entrepreneurial biotechnology firms take a leading role [in the R&D partnerships taking place in 1980s] when biotechnology first became relevant for the industry. The 1990s, however, see a different pattern with established, large pharmaceutical firms becoming more dominant, acting as nodal players with multiple partnerships with a variety of other companies" (p. 431). Interestingly, given the importance of external acquisitions of innovations and drug technologies from universities and biotechnology firms, Kneller (2003) reports that the role of the R&D function of large pharmaceutical companies is gradually changing from one where the basis for drug development follows in-house R&D, to one that builds on acquisitions. The latter provides the ultimate evidence for the effect the division of innovative labour, taking place in the pharmaceutical industry, has had for large pharmaceutical firms.

Figure 1.7: Number R&D partnerships in pharmaceutical biotechnology and in total in period 1975-1999

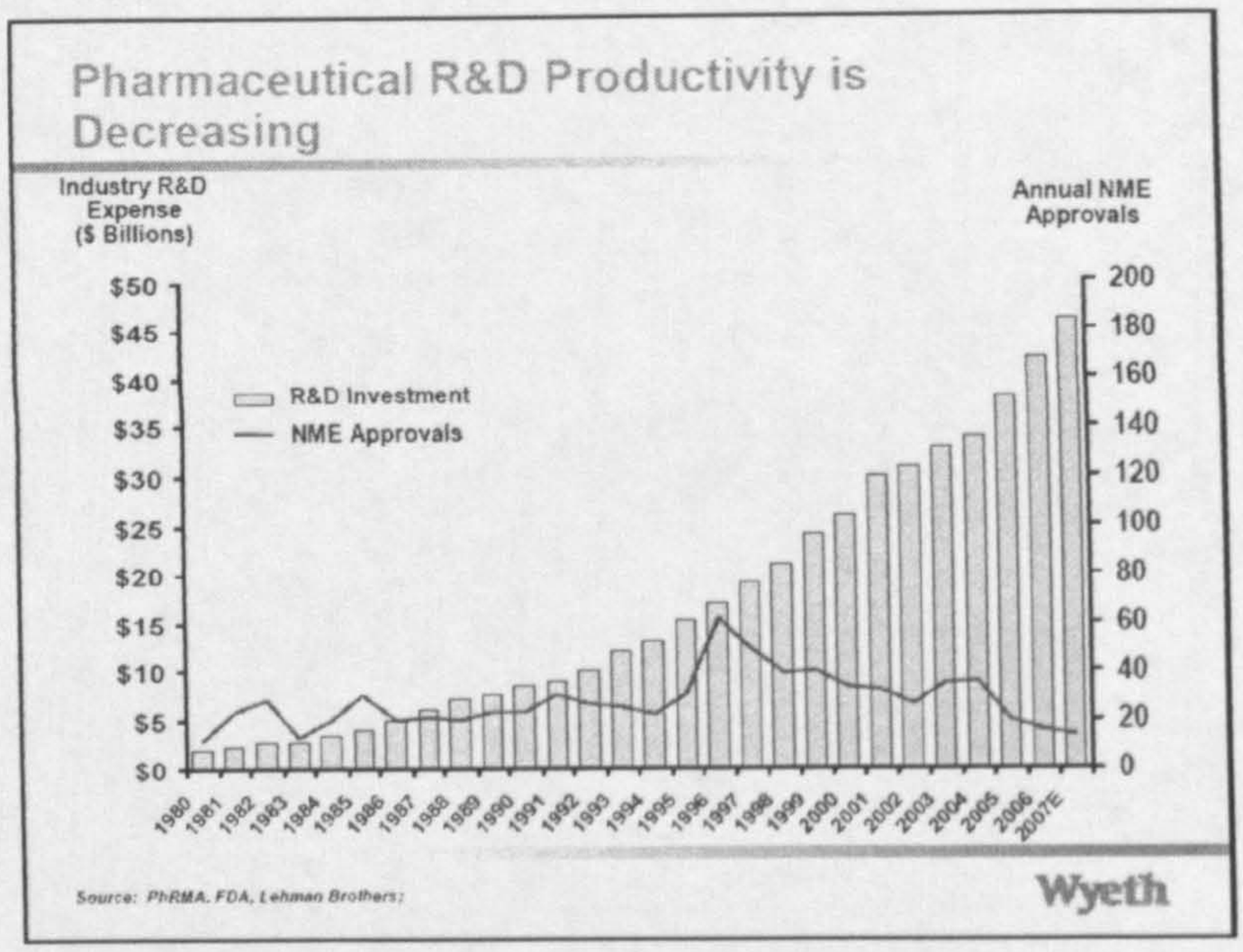


(Source: Roijakkers and Hagedoorn, 2006)

1.1.4 R&D inefficiency

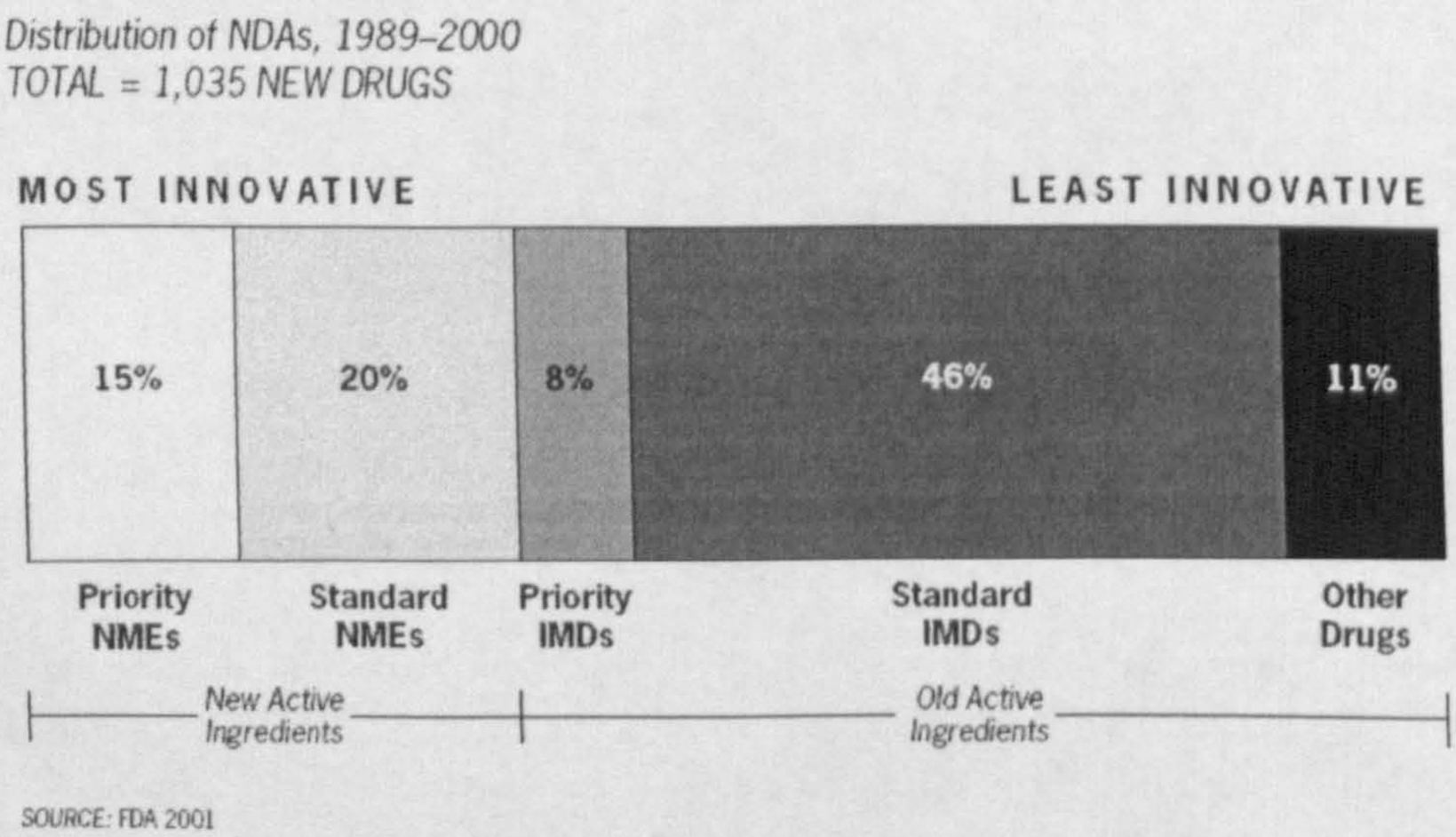
Interestingly, despite the promises of the new scientific and technological advances, the sharply rising R&D expenditure, number of collaborations and M&A's over the new knowledge regime, the pharmaceutical industry has found itself suffering R&D inefficiency. Figure 1.8 illustrates the R&D inefficiency by comparing the number of NME (New molecular entities) approvals with the increase in R&D expenditure, showing that whilst the R&D has increased by approximately 20 times in the period 1980-2007, the number of new drugs have, despite a peak around 1997, stayed stable over the entire period. This provides evidence that the pace of innovation in 2007 is similar to what it was in the beginning of the 1980s, when the pharmaceutical industry began its transition to the guided screening phase of drug discovery. Also, despite an increased trend of mergers & acquisitions from 1986, the Tufts centre for the study of drug development (2000) reports that the concentration of New Medical Entities (NME's) has declined since the 1960s.

Figure 1.8: Pharmaceutical R&D inefficiency



In addition to a low number of new drugs, the *National Institute for Health Care Management* reports that only 15% of new drugs approved in 1989–2000 were highly innovative priority NMEs, whilst the highest growth of new drugs are seen to have come from products that did not provide significant clinical improvement over existing drugs (Figure 1.9).

Figure 1.9: Distribution of New Drug Approvals (NDA's)



Interestingly, pointing particularly to the low number of drugs, Nightingale and Martin (2004) question the revolutionary effects of biotechnology, claiming that biotechnology rather "is following a well-established incremental pattern of technological change and 'creative accumulation' that builds upon, rather than disrupts drug development heuristics" (p. 566).

1.2 Theoretical motivation and focus for the research

The sections below seek to provide a brief introduction to the theoretical motivation behind and theoretical focus of the research.

1.2.1 Theoretical motivation

Cohen and Levinthal argue in their 1989 seminal paper, that "R&D develops the firm's ability to identify, assimilate and exploit knowledge from the environment" (p. 569), i.e. what they call absorptive capacity, and serve, in this way, as critical for a firm's innovative capacity. Cohen and Levinthal (1989) see absorptive capacity directly related to the firm's level of prior related knowledge, and hold that the ease of accumulating extramural knowledge will influence the firm's R&D spending necessary for a firm to innovate.

Holding this theory against the finding that despite an enormous increase in R&D the number of new drugs (i.e. innovations) have been decreasing in the pharmaceutical industry, the questions arise whether measuring absorptive capacity using R&D spending poses a problem for the classical absorptive capacity theory and whether other types of absorptive capacity are more important for innovation in this industry.

Looking at the literature, only one other type of absorptive capacity, i.e. relative absorptive capacity (Lane and Lubatkin, 1998) is introduced – a term seeking to capture the specific type of absorptive capacity that takes place in dyadic alliances between firms, e.g. R&D alliances between biotech firms and pharmaceutical firms. Given that big pharmaceutical firms' has increasingly relied on collaborations with small biotech firms, it is interesting to ask whether this type of absorptive capacity more important for the pharmaceutical firms than the one that is following their R&D?

In light of the above, the first aim of the research is to provide an understanding of how important R&D and collaborations have been for acquiring knowledge and the distinctive impacts they have had on pharmaceutical firms' ability to innovate and build innovative capabilities.

ii) Practice of absorptive capacity

Interestingly, whilst there has been a vast number of research taking use of absorptive capacity since the concept's introduction in 1989, only a few academics (e.g. Zahra and George, 2002) have sought to clarify the concept's components, processes and antecedents (Lane *et al.*, 2002 and 2006).

As a direct response to the above, the second aim of the research is to provide some empirical insight into the key processes and capabilities that enable a firm to acquire and exploit knowledge. In addition to the fact that an understanding of the practice underlying absorptive capacity represents a defined gap in the literature, the aim of better understanding the key processes by which firms acquire and exploit knowledge is highly topical due the R&D inefficiency that have taken place in the pharmaceutical industry in the recent years (see section 1.4).

1.3 Scoping the boundaries of the research

As seen above, the research aims seek to investigate the distinctive effects the different types of absorptive capacity have for innovation and capability building as well as to investigate the practice behind absorptive capacity. In this regard, it is important to note the following points:

i) The concepts 'absorptive capacity' and 'relative capacity' provide a theoretical basis for treating R&D and collaborations as distinctive knowledge acquisition strategies. Hence, although M&As can be regarded as an additional strategy to acquire knowledge, the fact that M&As are not treated as a separate type of absorptive capacity in extant literature makes this research focus solely on the importance R&D and collaborations play for acquiring knowledge and, subsequently, on their distinctive impacts on pharmaceutical firms' ability to innovate and build capabilities.

ii) The ability to acquire knowledge and exploit knowledge, which provides a basis for innovation and capability building, involves both individual and organisational learning. However, recognising the difficulty measuring the learning that is taking place at the various levels in an organisation, the research adopts a behaviourist approach, whereby measures for innovation and capacity building are seen to provide direct evidence that learning, at the various levels, successfully has taken place. As such, this research regards learning as only a part of the process of innovating and building capabilities. This particular approach was taken by Lane and Lubatkin (1998), which is one of the key papers that the research builds on. Consequently to the approach of not investigating learning processes as such, the research does not focus on the organisational learning, learning organisation or individual learning literature.

To summarise, the aims of the research are as follows:

i) to investigate the respective effects the two knowledge acquisition strategies, R&D and collaborations, have for big pharma's innovation and capability building.

ii) to identify the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge.

1.4 Thesis outline

An overview of the thesis's subsequent chapters is provided below.

- Chapter two: *Literature review*

The *Literature review* starts with some key references to illustrate the important role knowledge plays for innovation and the distinctive importance R&D and collaboration play for acquiring and exploiting new knowledge from external sources. Although the research is situated within the absorptive capacity tradition, the literature review not only provides a wider understanding of the distinctive importance R&D and collaborations have for innovation and capacity building but also recognises that the different strategies have complementary effects. The literature review then seeks to provide a deeper insight into the gap in the extant literature regarding the practice behind absorptive capacity. However, by presenting a theoretical model for how absorptive capacity works, as well as introducing the more specific findings regarding the factors that positively contribute to the development of absorptive capacity, the literature review draws a picture of the practice behind absorptive capacity. The literature review lays the basis for the formulation of the research questions.

- Chapter three: *Methodology*

The *Methodology* chapter seeks to outline the chosen methodology for the research project, presenting the research's underpinning epistemology, the overall research design and strategy, choice of sample, methods of investigation and approach to analysis. In short, whilst the investigation into the respective effects the two knowledge acquisition strategies, R&D and collaborations, have for big pharma's innovation and capability building (i.e. the first aim of the research) is achieved through the use of multiple case studies on three big pharma companies, including both document analysis of each of the firms as well as interviews, the investigation into the practise behind absorptive capacity (i.e. the second aim of the research) is pursued carrying out an in-depth case study on two large scale collaborations that one of the sample's firms used as means to enter into monoclonal antibodies. However, it is important to note that although the cross-case interviews were primarily used to investigate the first aim of the research, they are also used to pilot the second aim of the research. On the other hand, as the two aforementioned large scale collaborations were used as means to enter into a new area, the case study can also seek to provide insight into the effects of collaborations. As such, the case study also serves as an illustrative case for the first aim of the research. The findings obtained through the different methods are presented in distinctive chapters, respectively in chapters four, five and six.

- Chapter four: *Document analysis*

Chapter four presents the findings obtained through the *document analysis* on the selected firms, providing a picture of the firms' reliance on the different strategies and the distinctive effects they have had on the firms' innovations over time.

- Chapter five: *Cross-case interviews*

The *Cross-case study* seeks primarily to present the findings obtained through the cross case interviews towards the first aim of the research. However, given that cross-case interviews were used to pilot the second aim of the research, this chapter also seeks to present these findings.

- Chapter six: *Case study*

The aim of this chapter is to present the findings obtained through the in-depth case study on how two large scale collaborations were used to enter into a new area. The chapter seeks to present the key processes that enable the firm to acquire, assimilate, transform and exploit knowledge from a collaborator, as well as the effects the collaborations had on capability building. Contrary to the cross-sectional study, the case study seeks primarily to present the findings obtained towards the second aim of the research, whilst providing an illustrative case for the first aim of the research.

- Chapter seven: *Analysis and Discussion*

This chapter seeks to bring together and analyse the key findings obtained through the distinctive studies: i) document analysis, ii) cross-case interviews and iii) case study, and to position them theoretically.

- Chapter eight: *Conclusion and Recommendations for future research.*

This concluding chapter summarises the key findings obtained through the research as well as to provide some indications for future research.

Chapter 2:

Review of literature

2.1 Introduction

It is widely recognised that extramural knowledge is an important source for innovation (e.g. Schumpeter, 1934). In this context, it is interesting to note that pharmaceutical firms have increased their R&D expenditure as well as the number of collaborations with NBFs (New Biotech Firms) since the early introduction of biotechnology, in the 1980s. Assuming that these strategies have the potential to acquire new extramural knowledge, the expected effects of these efforts do not seem to have been capitalised, as these firms are currently experiencing R&D inefficiency. As such, the empirical evidence seems to show a reverse picture from that which is theoretically expected.

With this starting point, this literature review seeks to provide a deeper understanding of the distinctive importance R&D and collaborations play for acquiring and exploiting knowledge. However, in order to situate the research theoretically as well as to provide the necessary background knowledge for the research, the literature review takes a wider view, acknowledging not only that R&D and collaborations play additional roles for innovation, but also that the two strategies together might have complementary effects on innovation.

The chapter is organised as follows. The first section (2.2) starts with a brief review of the relationship between innovation and knowledge. Having provided this broader

background, the subsequent sections, 2.3 and 2.4, seek to introduce the distinctive importance of the role R&D and collaborations play for innovations. Specifically, whilst section 2.3 seeks to introduce the dual role R&D plays for innovation, i.e. knowledge creation as well as absorptive capacity, section 2.4 recognises that different collaborations exist and provides an insight into the specific contributions the different modes of cooperation have for innovation. Section 2.5, on the other hand, seeks to introduce a strand of literature investigating the complementary effects obtained through engaging in different strategies. The literature review then reviews a gap in the extant literature regarding the practice of absorptive capacity, i.e. section 2.6. Section 2.7 follows this up, seeking to introduce a theoretical model of how absorptive capacity works as well as specific empirical findings on key processes that enable a firm to acquire and exploit new knowledge.

2.2 Knowledge and innovation

The literature reveals an inter-dependent relationship between innovation and knowledge. Before providing a deeper insight into this relationship, the concepts of knowledge and innovation are defined below.

"Innovation is generally understood as the successful introduction of a new thing or method" (Luecke and Katz, 2003). Importantly, innovation must be distinguished from invention (Schumpeter, 1934), i.e. whilst invention is regarded as 'an idea made manifest', 'innovation is ideas applied successfully in practice', which have the potential to become profitable. Innovation can be either incremental or radical in nature. An incremental change involves small improvements, whereas a radical innovation involves major change (Tushman and Anderson, 1986).

Though a subject of ongoing debate in the field of epistemology, the classical definition of knowledge is *'justified true belief'* as in Plato's philosophy. In order to better understand the concept of knowledge it is useful to compare it to information. According to Nonaka and Takeutchi (1995) there are three differences between information and knowledge; "First, knowledge, unlike information, is about beliefs and commitment. Knowledge is a function of a particular stance, perspective, or intention. Second, knowledge unlike information is about action. It is always knowledge "to some end". And third, knowledge, it is about meaning. It is context-specific and relational" (p. 58).

Knowledge can be tacit or explicit (Polanyi, 1966). To summarise, tacit knowledge is regarded as personal, context-specific and therefore hard to communicate, whilst explicit knowledge typically refers to knowledge that can be communicated through formal language (Tsoukas, 2003).

The literature reveals an inter-dependent relationship between knowledge and innovation, with innovation both requiring and creating new knowledge.

Firstly, innovation needs new knowledge or a new combination of existing knowledge. The view traces back to the early writings of Schumpeter (1934), who argues that "breakthrough technologies result from bringing together existing knowledge from different sources". To illustrate this point, it is interesting to note that several empirical works have found that breakthrough innovations have resulted from developments outside the industries (e.g. Brock, 1975; Peck, 1962).

Secondly, the process of innovation itself creates new knowledge. The literature shows that knowledge is created through dynamic and active processes (Cook and Brown, 1999) taking place within specific contexts (Lave and Wenger, 1991). By being created in a

specific context, this 'situated knowledge' might not only be dependent on this context to be meaningful but might also be 'sticky' (von Hippel, 1994) and, hence, difficult to communicate or share. The latter seems to raise a key issue: if knowledge is situated and sticky, how can it be shared and transferred?

The following two sections seek to provide insight into the distinctive roles R&D and collaborations play for innovation.

2.3 R&D, innovation and capacity building

It is recognised that R&D plays a dual role in innovation.

i) The ability to use its knowledge resources to generate new knowledge. From a resource perspective, these knowledge resources result from a firm's unique bundle of resources, which it has acquired over time (e.g. Penrose, 1959; Wernerfelt, 1984; Dierickx and Cool, 1989). Barney (1995) added to this view, holding that it is the socially complex and tacit capabilities that yield competitive advantage.

ii) The ability to acquire and exploit extramural knowledge, i.e. absorptive capacity (Cohen and Levinthal, 1989, 1990 and 1994). Absorptive capacity is seen as a by-product of R&D[1]. By investing in R&D, the firm obtains a capacity to acquire and exploit knowledge that can be beyond the scope of their own internal knowledge-generating capabilities. However, as indicated by Cohen and Levinthal (1989) themselves, by acquiring new knowledge, "absorptive capacity represents an important part of a firm's ability to create new knowledge" (1989, p. 570).

[1] Cohen and Levinthal widen their view in their subsequent 1990 paper, emphasising that absorptive capacity also can be developed as a by-product of a firm's manufacturing operations.

The process of innovation is in itself found to underlie capability building. This lies at the heart of Leonard-Barton (1995), where she claims that "the primary engine for the creation and growth of technological capabilities is the development of new products and processes" (xiii). Leonard-Barton identifies specific internal activities, i.e.: problem solving, implementing and integrating, experimenting, as well as an external knowledge building activity, i.e. importing knowledge, arguing that these activities create flows of knowledge and direct them into new capabilities. By emphasising both internal and external knowledge building activities, Leonard-Barton (1995) seems to take account of both a firm's own knowledge resources as well as its absorptive capacity.

Capacity building is regarded as essential for a firm's competitive advantage; although a firm possesses competitive capabilities it is likely that this strategic advantage will erode as substitutes emerge. Building on the latter, *Teece et al.* (1997) argue that "firms must build dynamic capabilities that allow their ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p. 8). Referring directly to the idea that absorptive capacity plays a crucial role for the firm's ability to create new knowledge, Zahra and George (2002) argue that absorptive capacity has the potential to reconfigure internal competences in congruence with the environment and, as such, views absorptive capacity as a dynamic ability (Teece *et al.*, 1997).

Given that absorptive capacity is a role of R&D that matches the focus of the study, the remainder of this section seeks not only to critically review the concept of absorptive capacity, i.e. section 2.3.1 but also to further explore the link between absorptive capacity and dynamic capability, i.e. section 2.3.2.

2.3.1 Critical review of absorptive capacity

As mentioned above, the concept of absorptive capacity developed by Cohen and Levinthal (1989, 1990 and 1994). It is important to note that although the role of generating new knowledge was viewed as the key role of R&D prior to Cohen and Levinthal's 1989 paper, the idea that investing in R&D enables firms to acquire and exploit extramural knowledge did not originate with Cohen and Levinthal (1989). Tilton (1971), Allen (1977) and Mowery (1983) not only presented but also provided evidence for this view. According to a review paper of absorptive capacity by Lane *et al.* (2006), the particular contribution of Cohen and Levinthal (1989, 1990, 1994) was that they provided deep industrial organisation economics-based explanations of how and why R&D plays this role, in addition to giving it an intriguing name (p. 836). The aim of this section is to critically review absorptive capacity. The review is divided into two sections. The first section, i.e. 2.3.1.1, seeks primarily to introduce the key theory and evidence behind absorptive capacity, building primarily on Cohen and Levinthal's 1989, 1990 and 1994 papers. The second section, 2.3.1.2, then seeks to discuss the key concepts found in these papers, in light of the relevant literature.

2.3.1.1 Theory of and evidence for absorptive capacity

Cohen and Levinthal (1989) developed the pre-existing idea that R&D effort plays an additional role of keeping abreast of and assimilating technological knowledge (e.g. Tilton, 1971), by presenting it as learning or absorptive capacity. As emphasised by Cohen and Levinthal (1989) themselves and later confirmed by Lane *et al.* (2006), the link between R&D and learning had received little attention prior to this paper. Cohen and Levinthal (1989) see this lack of attention as a direct result of former economists, i.e. Arrow (1962) and Nelson (1959), treating technological knowledge in the public domain as a public good, like, for example, a radio signal. Although these economists were not denying the

existence of a cost of acquiring public knowledge, they regarded it as small in comparison to the ability to generate new knowledge. Importantly, Cohen and Levinthal (1989) contradict this view, claiming that the cost of learning may be substantial. They go on and argue that most of the cost is borne with the accumulation of stock of knowledge, which is what they regard as the firm's absorptive capacity.

Having introduced and situated absorptive capacity theoretically, Cohen and Levinthal (1989) seek to provide evidence for its role. In light of their claims that absorptive capacity learns from the environment, and that there are substantial costs associated with the acquisition and accumulation of new knowledge, Cohen and Levinthal (1989) propose that the incentives to learn should influence R&D spending. Although using technological opportunity, appropriability and ease of learning as distinctive incentives, Cohen and Levinthal (1989) proposed that the latter incentive will condition the influence on R&D of technological opportunity and appropriability. The different incentives to invest in R&D are presented below.

- Ease of learning

Cohen and Levinthal's concept of ease of learning refers to the characteristics of outside knowledge. The characteristics involve: the degree to which knowledge is targeted to the firm's needs, the degree to which a field is cumulative and the pace of advance of a specific field. In terms of the former point, whilst universities involved in basic research are seen to produce less targeted knowledge, contract research laboratories or input suppliers are seen to produce more targeted knowledge.

- Technological opportunity

The idea behind technological opportunity refers to "how costly it is for a firm to achieve technical advance" (p. 572). The quantity of knowledge made available by, for example,

government or university laboratories, or even equipment suppliers, i.e. sources that are external to the industry, and the "degree to which knowledge [...] improves the technological performance of the firm's manufacturing processes or products" (p.573), underlies the concept of 'technological opportunity'. Hence, technological opportunity is the opportunity to "achieve [at a lower cost] technical advance in a given industry" (p.572) that would otherwise be more costly.

- Knowledge appropriability

Cohen and Levinthal (1989) reach a counter-intuitive conclusion with regards to 'knowledge appropriability', whereby, contradicting established previous economics research, they argue that spillovers, which result from low degrees of appropriability, are an incentive to R&D as opposed to undermining it. The authors' reasoning is that as "only through its own R&D may a firm exploit the knowledge generated by its competitors" (p.575), firms find an incentive to invest in R&D, when that knowledge is characterised by lower appropriability, in order to exploit their competitors' knowledge.

Using R&D intensity (i.e. R&D expenditure as a percentage of business unit sales) as the dependent variable, Cohen and Levinthal (1989) developed a model allowing them to test both the effects of the determinants of ease of learning and their influence of technological opportunity and appropriability on R&D intensity. Business unit level data covering the period 1975-1977 were obtained from the Federal Trade Commission's Line of Business and data on inter-industry differences in technological opportunity and appropriability from Levin *et al.* (1983, 1987).

The model is tested in both Cohen and Levinthal's 1989 and 1990 papers, and the results of the tests generally confirmed their hypotheses. Firstly, as hypothesised, Cohen and Levinthal (1989) find that 'there exist differences in characteristics of the fields, such as

pace of advance, cumulativeness, and targetedness, that affect the ease of learning, which then influence the technological opportunity on R&D spending" (Cohen and Levinthal, 1989, p. 585). The technological opportunity also associated with the relatively less targeted basic knowledge is found to elicit more R&D spending than applied knowledge does. In terms of appropriability, spillovers are seen to have a positive effect on R&D, i.e. the more spillovers found in the environment, the more absorptive capacity is required to acquire this knowledge. Furthermore, the appropriation incentive was found to be even greater when associated with basic knowledge.

Cohen and Levinthal (1989, 1990) see clear implications of why a firm invests in basic research, highlighting both first and second mover advantages. In terms of first mover advantages, Cohen and Levinthal (1989, 1990) claim that "firms may invest in basic research less for the particular results than to be able to identify knowledge generated by universities or government laboratories, and thereby gain a first mover advantage in exploiting new technologies" (p. 593). Second mover advantages, on the other hand, refer to the view that basic research enables the firm to better take advantages of the spillovers of the competitors' innovation. Interestingly, Cohen and Levinthal (1989, 1990) contrast with Nelson (1959) in terms of the importance diversification plays for investment in basic knowledge. Specifically, whilst Nelson (1959) argues that for a firm to take advantage of basic research, it needs to be relatively large with a diverse portfolio of products, Cohen and Levinthal (1989) see investment in basic research as related to a firm's technical advance rather than its diversification, as illustrated in the following quote "[...] as a firm's technological progress development depends on an increasing number of fields of basic science, a firm will increase its basic research" (Cohen and Levinthal, 1989, pp. 593-594).

Though testing the same relationships in the 1990 paper as those in the 1989 paper Cohen and Levinthal (1990) provide a deeper insight into the processes behind the concept of

absorptive capacity, by drawing on theories on both individuals' cognitive structures and problem solving as well as more general theories in innovation management. The key processes are introduced below.

- Prior knowledge and cumulativeness

Cohen and Levinthal (1990) used research on individual learning and problem solving to provide a deeper understanding of absorptive capacity. Having found that problem solving and learning develop in a similar way, i.e. by building on prior related knowledge, Cohen and Levinthal (1990) view absorptive capacity as a function of prior related knowledge and, as such, reveal the cumulative nature of absorptive capacity. This cumulative nature draws attention to individual absorptive capacities and the firm's prior investment in them as well as providing a deeper explanation of the importance of basic knowledge.

The new view seems clearly different from the one that was introduced in their 1989 paper, where absorptive capacity was simply seen as a stock of knowledge. It is interesting to note the human aspect of absorptive capacity; Cohen and Levinthal (1990) redefine absorptive capacity as the "ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (p. 2). Although little explanation is given, Lane *et al.* (2006) claim that this new definition "represents a single loop learning process (modifying actions) rather than a double-loop learning process (modifying assumptions)" (p. 838) and, as such, connect the new definition to Argyris and Schon's (1978) learning theory.

Although emphasising the importance of individual absorptive capacities, Cohen and Levinthal (1990) state that "a firm's absorptive capacity is not, however, simply the sum of individual absorptive capacities, and it is therefore useful to consider what aspects are distinctively organisational" (p. 4). An insight into the organisational aspects that allow a firm to acquire, assimilate and exploit is provided below.

- Efficient knowledge transfer and redundancy of knowledge

In terms of acquiring new knowledge into the firm and assimilating it through the firm, Cohen and Levinthal (1990) place great importance on individuals who stand at the interfaces between the firm and the external environment, as well as those who stand at the interfaces between the different sub-units within the firm. Although one of the aims of these individuals is to translate the knowledge, Cohen and Levinthal (1990) emphasise that an efficient knowledge transfer is only possible if the relevant employees have a sufficient level of background knowledge. The latter reflects the more general idea that shared knowledge is essential for communication. However, at the same time as shared knowledge improves communication, Cohen and Levinthal (1990) highlight the importance of diversity of knowledge for innovation. As such, Cohen and Levinthal (1990) see an organisational trade-off between redundancy and diversity of a firm's knowledge, stating: "assuming a sufficient level of knowledge overlap to ensure effective communication, interactions across individuals who each possesses diverse and different knowledge structures will augment the organization's capacity for making novel linkages and associations – innovating beyond what any one individual can achieve" (p. 5). Recognising that cross-function interfaces affect organisational absorptive capacity and innovative performance, Cohen and Levinthal (1990) urge not only tight cooperation between complementary departments within a firm but also for the firm to develop a sound knowledge of where to obtain useful complementary expertise both within the firm and in the firm's environment. Building directly on Nelson and Winter (1982), Cohen and Levinthal (1990) claim that much of a firm's knowledge processing relies on tacit processes. Although it is plausible that tacit knowledge poses a problem for absorptive capacity, Cohen and Levinthal (1990) only recognise the problem of the tacit knowledge processing for acquiring new firms, i.e. due to the tacit processes behind firm's knowledge processing a firm cannot easily be acquired and quickly integrated into a new firm.

Although both cumulativeness and knowledge transfer are key processes behind absorptive capacity, Cohen and Levinthal (1990) see clear implications of the former for the future development of a firm`s absorptive capacity as well as its innovative performance (p. 6). This is articulated in the following two aspects:

i) Positive returns: "Accumulating absorptive capacity in one period will permit its more efficient accumulation in the next" (p. 6). On the other hand, should the firm fail to acquire relevant knowledge in a specific time, it may lock the firm out of future technological developments.

ii) Predictive enhancement: "The possession of related expertise will permit the firm to better understand and therefore evaluate the importance of intermediate technological advances that provide signals as to the eventual merit of a new technological development" (p. 6). This point is confirmed in Cohen and Levinthal's 1994 paper, making the authors re-define the definition of absorptive capacity yet again, i.e. "not only [does absorptive capacity] permit firms to exploit new, valuable developments, but also to envision better their emergence" (p. 244).

2.3.1.2 Critical review of key concepts

Although Cohen and Levinthal provided a new perspective of this secondary role played by R&D, the review of their 1989, 1990 and 1994 papers leaves a couple of critical questions regarding their theory and measurement. Firstly, there seems to be an inherent problem introducing absorptive capacity as a stock of or function of prior related knowledge: if a firm has obtained some knowledge in a specific area does that not mean that the firm already has a capability in the knowledge area and, as such, do firms really need absorptive capacity? Secondly, there seems to be a problem with how Cohen and

Levinthal (1989, 1990) model and measure absorptive capacity: if absorptive capacity is a learning process, why do they use the static measure of R&D to measure it? Also, given that knowledge can be sticky, is the effort in the shape of R&D spending really a way of un-sticking or de-situating knowledge? And similarly, to what extent does tacit knowledge pose a problem for absorptive capacity? Thirdly, although introducing absorptive capacity as crucial for innovation, it is interesting to note that Cohen and Levinthal never sought to test the real impact of absorptive capacity on innovation, though indicating clear implications of investing in a large, basic knowledge base. In relation to the latter point, the remainder of this section seeks to investigate the impacts a basic knowledge base and a large knowledge base have on innovation, in light of relevant literature. As a last point, the review seeks to provide some insights into the long term effects of absorptive capacity.

Large scope of research and innovation

As mentioned above, Cohen and Levinthal (1989, 1990) provide the insight that a large scope of research, where a firm invests in broad knowledge bases, is seen to both increase the likelihood for a firm to capture developments in various technological domains and to see linkages between the different knowledge bases, which the firm probably would not be able to make, had it invested in a narrower knowledge base.

Cockburn and Henderson (1994) elaborate further on the latter point, holding that a wider knowledge base has the potential to create combinative or integrative capabilities. A consequence of the above is that a wider knowledge base is seen to have a higher probability of producing radical innovations than a narrower base has.

Sustaining a broad scope of research is, however, expensive and rarely affordable for small firms. In effect, small firms tend to specialise in specific niches by building on a narrower knowledge base (Patel and Pavitt, 1997), leaving the larger firms to develop broad

technological capabilities from a larger scope of knowledge. However, even for large firms, a large scope of knowledge can, after a certain point, result in decreasing returns. Brusoni *et al.* (2002) confirm this with their findings of a fuzzy relationship between breadth of technological knowledge and firm performance for large pharmaceutical companies.

Having provided this more general background, it is interesting to note that Van den Bosch *et al.* (1999) make explicit use of the concept of integrative capability when investigating the role of absorptive capacity in the process of co-evolution.

Building on the idea that knowledge cannot be separated from how it is currently organised and that absorptive capacity depends on a collection of individual capabilities, they propose that absorptive capacity is dependent on organisational form and integrative capabilities.

By carrying out two longitudinal case studies of firms moving through turbulent environments, they not only show that integrative capabilities and organisational form influence absorptive capacity, i.e. the level of prior related knowledge, but also find that through the feedback loops created, absorptive capacity mediates organisational adaptation, offering a new insight into absorptive capacity.

Basic knowledge and innovation

In addition to a broad knowledge base, Cohen and Levintal (1989) emphasise the importance of basic research. Traditionally, basic research is considered as aiming at understanding a phenomenon without specific applications in mind, whilst applied research seeks to produce knowledge for a specific end-use (e.g. Nelson, 1959).

As seen above, Cohen and Levinthal (1989) refer directly to Nelson's seminal 1959 paper. Nelson (1959) takes a broad view of basic research, which to some extent embraces some of the advantages presented under 'large knowledge base', i.e. whilst the outcomes of basic research in general are more unpredictable (due to its less practical nature), a broad basic knowledge base will help to understand where, or in which path, the outcome would yield benefits.

As seen above, having provided evidence that R&D has an ability to exploit external knowledge and that basic research elicits more R&D spending, Cohen and Levinthal (1989, 1990) further use first and second mover advantages as explanation for why firms "may invest in basic knowledge when the preponderance of findings spill out into the public domain" (Cohen and Levinthal, 1989: 593). First mover advantages relate to the fact that basic research has potential to create breakthroughs (according to Nelson (1959), more than applied research) but also that it enables a firm to exploit technological opportunities. Second mover advantages, on the other hand, refer to the view that basic research enables the firm to better take advantages of the spill-overs of the competitors' innovation.

It is interesting to note that a year after Cohen and Levinthal's (1989) paper, Rosenberg (1990) criticizes this use of scientists' ex ante intention for performing research as a criterion for distinguishing between basic and applied. Rosenberg claims that the knowledge acquired in any research is unpredictable, illustrating that few research projects are conducted without particular specifications in mind, and that an increase of basic knowledge has resulted from more specific applications. Also, whilst Cohen and Levinthal emphasise the importance of firms' ability to exploit new extramural knowledge, Rosenberg (1990) sees investment in basic research as important as it enables firms to evaluate the technological opportunities. Lim (2004) suggests that the ability to evaluate technologies implies a narrower view of basic research than that offered by Nelson (1959).

This view of basic research reveals a deeper or 'more rooted' understanding of a phenomenon with the immediate implication of offering a greater understanding of the subject at hand, e.g. applied research and, hence, equipping the firm with the ability to evaluate it (Lim, 2004).

In light of the growing theoretical claims of the importance played by basic research for innovation, several works have sought to investigate the relationship between basic research and innovation at a firm level empirically. Seeking to investigate the interface between for-profit and public research, Cockburn and Henderson (1998) is a particularly important paper in this regard.

In summary, initiating their research using interviews, Cockburn and Henderson (1998) not only address the importance played by public research for the pharmaceutical industry, but also provide evidence that the conduct of leading edge research inside the firm is needed in order to take advantage of publicly generated research. Carrying out leading edge internal research and obtaining access to public research were also seen to be dependent on hiring the best possible people, rewarded on the basis of the public rank hierarchy, but also being actively involved with their public sector counterparts (p. 162) through forming collaborations.

The finding that ability to exploit external knowledge depends not only on carrying out leading edge research, but also on hiring expert people, (Cockburn and Henderson, 1998) not only provides evidence for the key idea behind Cohen and Levinthal's theory but also supports the importance of high individual absorptive capacities. However, Cockburn and Henderson (1998) use the latter finding, i.e. that to access and exploit knowledge involves collaborations with the public sector, to conclude that "the development of absorptive

capacity requires more than simply conducting a certain amount of fundamental research in-house" (p. 159)

Inspired by the finding that collaborations play a key role for accessing knowledge, Cockburn and Henderson (1998) seek to investigate their distinctive effects on research performance quantitatively. Specifically, by matching co-authoring data of a sample of ten large pharmaceutical firms to their research performance, Cockburn and Henderson (1998) found substantial returns to connectedness. Then, linking this co-authoring data with data obtained from surveys regarding the firms' organisational structure, e.g. the extent to which the firms were associated with pro-publication attitudes or more dictatorial styles, they found, as expected, connectedness correlated with a supportive internal organisation.

Although based on a small sample, the study directs criticism towards Cohen and Levinthal's emphasis on the sole use of internal R&D efforts for the development of absorptive capacity.

Long term effect of absorptive capacity

Bierly and Chakrabarti (1996) seek to identify generic knowledge strategies and their effects over time. Distinguishing between four strategic choices, i.e. internal vs. external learning, radical vs. incremental learning, learning speed and breadth of knowledge, Bierly and Chakrabarti (1996) investigate their adoption in 21 U.S. pharmaceutical firms in the period from 1977 to 1991.

The investigation revealed four distinctive groups according to their knowledge strategies: 'innovators', 'loners', 'exploiters' and 'explorers'. 'Innovators' are described as the "most aggressive learners in the sense that they most effectively combine internal and external learning [...], focus on both radical and incremental learning, and are one of the fastest

learners" (p. 128). 'Loners' are viewed as the most ineffective learners even though they spend more than the industry average on R&D. The inefficiency is linked to the fact that they are slow in applying new knowledge and that they have few science linkages. The 'exploiters' group is characterised by concentrating more on external learning than on internal learning, which is illustrated by a low amount of R&D and a high level of science linkage, though a narrow knowledge base. Their focus is clearly on incremental learning. The last group – the 'explorers' – is defined by having high levels of radicalness in 1982-1991, though they are roughly the same as the industry average in each of the other areas, i.e. they seek a good balance between external and internal learning and have a relatively high level of science linkages. Their main focus is on radical innovations.

The analysis showed that the characteristics of the knowledge groups remained stable over time, with innovator and explorer groups characterised by higher profit levels. In case of movement, this only took place between the similar knowledge groups, i.e. innovators – explorers vs. loners – exploiters. The fact that the most innovative group, i.e. the 'innovators', is the one which not only combines internal and external learning best but remains one of the groups with the highest profit over time provides clear evidence for the importance played by absorptive capacity.

2.3.2 Absorptive capacity – a dynamic capability

As seen in section 2.3 (introduction), absorptive capacity is regarded as a 'dynamic capability'. As such, this section seeks to explore the similarities between the different concepts, both in terms of definition and nature of the two concepts.

As seen above, Teece *et al.* (1997) define a dynamic capability as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly

changing environments" (p. 8). Building on the specific features of absorptive capacity presented in the section above, i.e. the capacity to predict and value technological developments, but also to acquire and exploit this knowledge, which is crucial for knowledge creation and capacity building, this research seems to suggest that absorptive capacity integrates, builds, and reconfigures internal and external competences.

The fit between absorptive capacity and dynamic capability is further supported by the concepts' nature. Teece *et al.* (1997) hold that a dynamic capability is embedded in managerial and organisational processes (taking the form of routines), shaped by the asset position (i.e. technology) and evolutionary path (Teece *et al.*, 1997). The processes are further seen to have three aims: i) coordination/integration, ii) learning and iii) reconfiguration/transformation. Whilst the aim of integration seems to correspond to the first dimension of absorptive capacity, i.e. acquisition of knowledge, learning and later a reconfiguration of the firm's capabilities are seen to be more the results of a successfully developed absorptive capacity. Furthermore, both Cohen and Levinthal and Teece *et al.* (1997) emphasise the importance of common language for learning to take place. Path dependence is also clearly developed in both the frameworks, where both emphasise that 'history matters', whereby the 'previous investments constrain the firm's future behaviour'. In fact, as seen in the section above, failing to invest in certain knowledge might cause the firm to experience being locked out of future developments.

A more sophisticated model of how absorptive capacity fits the concept of dynamic capability is provided by Zahra and George (2002). In the same way as Teece *et al.* (1997) see capabilities build on processes, Zahra and George (2002) hold the various dimensions of absorptive capacity, i.e. knowledge acquisition, assimilation, transformation and exploitation, as distinctive capabilities, each governed by routines and processes. It is by

these various capabilities interacting that a firm obtains a dynamic capability. This framework will be presented in more depth in section 2.6.

2.4 Collaborations, innovation and capacity building

There are clear limitations to firm knowledge resources and, as such, firms form collaborations with other firms to generate or acquire new knowledge.

Interestingly, in the light of competition becoming increasingly knowledge based, there has been a shift from traditional resource or risk-sharing collaborations to collaborations with learning as the core goal (Hamel, 1991). Subsequently, 'learning alliances' have been regarded as strategic means to learn and develop new capabilities faster (e.g. Grant and Boden-Fuller, 1995).

With the development of the construct of absorptive capacity, it is interesting to note that a strand of research builds on the assumption that the processes underlying absorptive capacity capture the steps involved in inter-organisational learning and has, as such, focused on the role absorptive capacity plays for inter-organisational learning, e.g. the importance of R&D intensity for acquiring knowledge from a collaborator (Mowery *et al*, 1998).

Lane and Lubatkin's (1998) paper must be seen as a reaction to this coupling between absorptive capacity and inter-organisational learning, giving rise to a new type of absorptive capacity taking place in dyadic collaborations, i.e. what they call relative absorptive capacity. Furthermore, whilst acknowledging the idea that the processes behind absorptive capacity capture those processes taking place in inter-organisational learning, Lane and Lubatkin (1998) argue that inter-organisational learning is a result of relative

factors between the collaborating firms. Whilst relativity factors clearly is not an aspect included in the classic absorptive capacity theory, Lane and Lubatkin (1998) in turn claim that the way Cohen and Levinthal introduce absorptive capacity (1989, 1990, 1994) suggests that a firm has an equal capacity to learn from all other firms (Lane and Lubatkin, 1998, p. 461).

With this as a starting point, the aim of the paper is to test the impact relative factors have on inter-organisational learning. In line with the argument that the processes behind absorptive capacity mirror the steps in inter-organisational learning, Lane and Lubatkin (1998) view the dimensions found in Cohen and Levinthal's (1990) definition, i.e. 'value, assimilate and apply new knowledge', as distinctive abilities. Building on the literature, Lane and Lubatkin (1998) derive a set of hypotheses of the specific processes underlying the different abilities, i.e. to acquire, assimilate and exploit knowledge would contribute to inter-organisational learning. Specifically, building directly on Cohen and Levinthal's (1990) emphasis on the importance of basic knowledge over applied knowledge, Lane and Lubatkin (1998) propose that the relevance of a student firm's basic knowledge to the teacher's knowledge base will be key for *'acquiring new knowledge'*. Furthermore, taking on board the point that processing of knowledge is tacit and hence not observable (Nelson, 1959 and Cohen and Levinthal, 1990), Lane and Lubatkin (1998) develop two proxies for the assimilation process: i) compensation practices and ii) organisational structure, arguing that the assimilation process will affect both. Having identified some proxies for 'assimilation of knowledge', Lane and Lubatkin (1998) hypothesise that a similarity of student firm's and teacher firm's compensation practices and organisational structure will be positively associated with learning. Building directly on Grant (1988), who states that "a firm develops preferences for projects of a given type, size, and risk level, and favours strategies dependent upon certain key success factors, stages of product life cycle, or product-market-positions" (Lane and Lubatkin, 1998, p. 466), Lane and Lubatkin (1998)

propose that the dominant logics (i.e. 'the common thread') of a firm's commercial objectives will determine how the firm *'exploits knowledge'* and, as such, hypothesise that the similarity between the collaborating firms on this aspect will positively contribute to learning.

Data on the various measures were collected from a range of primary and secondary sources. In this context, it is important to note that the dependent variable, i.e. the extent to which the sample collaborations have achieved learning and/or capability building, relied on expert evaluations. Testing the factors' distinctive contribution to learning on 69 collaborations between 'student' big pharmaceutical firms and 'teacher' biotechnology firms, Lane and Lubatkin (1998) confirmed most of the hypotheses, as summarised below.

Ability to acquire. Lane and Lubatkin (1998) actually find support for their hypothesis that a basic knowledge base enhances inter-organisational learning.

Ability to assimilate. Whilst Lane and Lubatkin (1998) find strong support for the importance of similarities of compensation practices between the two collaborating firms for inter-organisational learning, they find, on the other hand, only partial support for the importance of the similarities between organisational structures between the collaborating firms for inter-organisational learning. Specifically, of the four measures for organisational structures, Lane and Lubatkin (1998) only find the predicted association between similarity of lower management formalization and similarity of research centralisation.

Ability to exploit. Lane and Lubatkin (1998) find strong support for dominant logics.

By obtaining support for their hypotheses, Lane and Lubatkin (1998) not only provide evidence for inter-organisational learning but also insight into the processes governing

knowledge processes and is, as such, the only paper that seeks to understand the key processes involved knowledge transfers in collaboration. By extending the use of absorptive capacity from firm level to a learning dyad construct, Lane and Lubatkin (1998) offer a re-conceptualisation of Cohen and Levinthal's concept of absorptive capacity.

However, despite their contribution, it is important to point out that 'learning alliance' is a theoretical concept; in reality, alliance or collaboration is a wide term which consists of several modes of collaborations. Also, the behaviouristic approach used to confirm that learning had taken place (building on coherence between expert evaluations), provided no insight into what had been learnt, the types of innovations emerging or the capabilities built. Finally, the fact that Lane and Lubatkin's (1998) research focuses on the learning taking place between pharmaceutical firms and biotechnology firms raises a further question: would their findings generalise to other organisations, e.g. universities, which, in theory, could differ on the independent variables, e.g. different knowledge bases, compensation practises, organisational structures and/or logics of problem-solving?

In direct response to the above, although Lane and Lubatkin (1998) provide evidence for learning and capability building, it is important to provide a deeper understanding of the different modes of collaborations in order to further understanding of the importance inter-organisational collaborations play for innovation. Focusing specifically on firm-firm collaborations and firm-university collaborations, a deeper understanding of the most common modes of collaborations of the 'groups', the underlying motivations of firms to enter into firm-firm as well as firm-university collaborations as their distinctive impacts on innovation, is addressed below.

2.4.1 Firm-firm collaborations

An explanation of various innovation-motivated modes of cooperation is found in Hagerdoorn (1990). This paper was a direct response to the trend in academic research of treating all collaborations as joint ventures or grouping several fundamentally different collaborations as a 'strategic partnership'. Summarised below, the list of modes of collaboration must be seen as a continuum, based on the degree of organisational interdependence, with joint venture and unilateral technology flows on the extreme ends.

Joint venture

A joint venture is a commercial undertaking entered more than one parties aiming at cooperating with each other, sharing costs, exploiting new technologies, or gaining access to new markets. The subject of cooperation in joint ventures can involve companies sharing "R&D as a specific company objective in addition to production, marketing, sales etc" (Hagerdoorn, 1990, p. 20). In fact, the research component can play such an important role in joint ventures that they become "research corporations [...] [i.e.] joint ventures with distinctive research programmes" (Hagerdoorn, 1990, p. 21).

Joint R&D agreements

A joint R&D agreement is an umbrella term for "joint R&D pacts and joint development agreements which establish joint undertaking of R&D projects with shared resources" (Hagerdoorn, 1993, p. 374). This also involves cooperation on legal and managerial matters with the ultimate aim of dividing R&D among different partners, with each of them working on different aspects of a project. Joint research pacts and joint development agreements have in common the fact that the parties involved join together in R&D with the aim of reducing costs and risks, and seeking synergy, when pursuing similar innovations. Of a similar nature, but encompassing a much wider variety of agreements, are technology exchange agreements, which are characterised by "companies negotiat[ing]

the allocation [among them] of established knowledge or artefacts generated by one partner or through collective efforts" (Hagerdoorn, 1990, p. 23). Prior to entering comprehensive joint ventures, firms explore the potential benefits of cooperation by applying agreements such as: "joint research pacts; joint development agreements; technology [exchange and] sharing agreements" (Hagerdoorn, 1990, p. 22).

Equity investments

Equity investments, i.e. a company's acquisition of another company's equity, can be considered "as a form of co-operation between companies which in the long run could affect the technology performance of at least one 'partner'" (Hagerdoorn, 1990, p. 24). Equity investments can lead to: the acquirer merely assessing the acquired company's expertise, without seeking complete integration of its operations with those of the acquired company; or the acquirer having significant influence over the operations of the acquired company; or the acquirer having full control over the acquired company. These different levels of involvement are determined by the amount (and type) of equity that the acquirer has acquired and the presence of research or other commercial contracts between the parties. In particular when research contracts are in place between the parties, and even more when the acquired company also buys shares in the acquirer (cross-holding), the equity investment "can be understood as a case of co-operation" (Hagerdoorn, 1990, p. 24).

Customer-supplier relations

A further form of cooperation is given by 'customer-supplier relations' which "can be divided into a number of forms of partnerships such as coproduction contracts, comakership relations, and research contracts that regulate R&D cooperation in which one partner, usually a large company, contracts another company, frequently a small specialized R&D firm, to perform particular research projects" (Hagerdoorn, 1993, p. 375).

The first of these three is characterised by a leading company supplying "the technology and critical components, and other companies manufacture less critical components and assemble final products" (Hagerdoorn, 1990, p. 24). The second normally implies "long-term contracts between users and suppliers, with users out-sourcing a part of their production process to suppliers of sub-assemblies" (Hagerdoorn, 1990, p. 25), with cooperation between users and suppliers on support activities such as quality control, but planning and specifications set by the users. The research contracts, instead, "regulate R&D cooperation in which one partner, usually a large company, contracts another company, frequently a small one, to perform particular research projects" (Hagerdoorn, 1990, p. 25).

Unilateral technology flows

The last group of cooperations considered in Hagerdoorn's 1990 paper is made up of unilateral technology flows, where one party, which has proprietary rights over a technology, gives another party the right to use these rights, often in the legal form of "second sourcing and licensing agreements" (Hagerdoorn, 1993, p. 375). Where the technology flow is reciprocal, i.e. where the parties swap rights between them, one enabling the other to use the reciprocal rights, it becomes a technology exchange as addressed above.

Having furthered the understanding of the characteristics of different types of firm-firm collaborations, Hagerdoorn (1993) seeks to advance an empirical understanding of the motivations of firms to engage in strategic technology partnering as well as inter-sector differences in using them. Interestingly, however, whilst Hagerdoorn identifies different innovation-motivated collaborations in his 1990 study, he narrows down his sample of interactive modes to strategic technology alliances in his follow-up 1993 study, defining them as "those interfirm cooperation agreements which are aimed at improving the long-

term perspective of the product market companies involved" (Hagerdoorn, 1993, p. 375). The new emphasis on strategic technology alliances builds directly on a former study of his (Hagerdoorn and Schakenraad, 1990), where they found that R&D joint ventures and research corporations, joint R&D agreements and equity investments were found to be more than 85 percent strategically motivated [... whilst], "only a small portion of the technology exchange agreements, one-dimensional technology flows and customer-supplier relationships are expected to be strategically motivated, with the exception of a subgroup within the latter group, i.e. research contracts" (Hagerdoorn, 1993, p. 375). This result was obtained through the use of the MERIT-cooperative agreements and technology indicators (CATI) databank, including information on nearly 3021 technology cooperation agreements.

Building on the same database in Hagerdoorn's (1993) study as Hagerdoorn and Schakenrad (1990), though for the former research using a sample of over 4,000 technology alliances found in several sectors, Roijakkers and Hagerdoorn (2006) obtain the following findings: i) strategic technology partnering in high tech is strongly related to R&D cooperation, whilst market access is a dominant feature of partnering in low and medium industries; ii) interestingly, despite finding that high tech industries are strongly related to R&D cooperation, the motive of performing basic research is only of some relevance in biotechnology and new materials; iii) lastly, whilst complex inter-organisational modes of cooperation are motivated by both market and technology mediated objectives, the motivation for using contractual strategic technology alliances is primarily short-term technological achievement, particularly focused on applied knowledge.

Although focusing solely on the pharmaceutical biotechnology industry, Roijakkers and Hagerdoorn (2006) seem to confirm the above. Seeking to analyse the major R&D

partnering trends in the pharmaceutical biotechnology industry in the period 1975-1999, using a total of 1,469 global R&D agreements found in the MERIT-Cooperative Agreements and Technology Indicators, Roijakkers and Hagerdoorn (2006) find two trends.

i) Non-equity based modes in preference to equity modes. Roijakkers and Hagerdoorn (2006) attribute the high R&D costs and short technology cycle as key reasons for the reliance on non-equity based modes, arguing that "by engaging in a portfolio of flexible, contract based research partnerships, firms are able to monitor the development of several contract-based partnerships" (p. 434).

ii) Roijakkers and Hagerdoorn (2006) find a change in collaborative behaviour, i.e. whilst in the period 1975-1985 research pacts were seen as the most popular mode of collaboration, joint R&D agreements were the most frequently used mode in the period 1985-1999. Roijakkers and Hagerdoorn (2006) see the increasing reliance on joint R&D over research pacts as a result of big pharmaceutical firms having internalised the new biotech knowledge, having by this time set up research centres themselves and, as such, actively seeking joint R&D collaborations rather than just outsourced R&D projects.

That a research-intensive industry like the pharmaceutical biotechnology sector seeks research collaborations over equity modes is in clear congruence with Hagerdoorn (1993). Furthermore, despite the reported change in pharmaceutical firms' partnering behaviour in the 1980s, i.e. from research pacts to joint agreements (Roijakkers and Hagerdoorn, 2006), Hagerdoorn's (1993) specific findings on monitoring technological developments, complementary skills and reduction of the innovation time span as the overarching motivations for partnering in biotechnology in the period 1980-1989, seem to be in clear congruence with Roijakkers and Hagerdoorn (2006).

Interestingly, despite the variety of collaborations and the distinctive motivations found for using them, the literature seems to provide little understanding of their distinctive effects. Whilst it is likely that the use of quantitative methods would prove difficult given the multitude of modes of collaborations that exist, some insight into this topic could have been obtained through the use of more qualitative research methods. Despite this gap, there are several empirical works that provide evidence for the importance of collaborations as a whole for learning. Powell *et al.* (1996) is a particularly important study in this regard.

Being motivated by the increase in the number of collaborations in biotechnology, Powell *et al.* (1996) seek to investigate the contribution of collaboration to organisational learning. Basing their study on a relational database of 225 dedicated biotechnology firms and their partners (pharmaceutical firms, hospitals etc) for the period 1990-1994, Powell *et al.* (1996) find, as anticipated, not only that in a field of rapid technological development, the locus of innovation is in networks, but also that the centrality of this network is crucial, as it provides access to crucial information needed for internal growth. Interestingly, they find that it is diversity of R&D ties and the experience gained from managing and learning from them that produce the desired centrality. On this basis, Powell *et al.* (1996) conclude that the development of absorptive capacity and the acquired skills in managing collaborations, as well as an increased awareness of new projects and an enhanced reputation as a valuable partner, are serendipitous benefits of collaborations. Hence, whilst Lane and Lubatkin (1998) focus on the relative factors that enable inter-organisational learning, Powell *et al.* (1996) provide an understanding of the long term effect inter-organisational collaboration has on firms' absorptive capacity.

Despite the evidence above, it is interesting to note that Arora and Gambardella (1994b) hold that pharmaceutical firms' collaborations with universities are more basic research-focused than their collaborations with firms and, hence, are more likely than the

biotechnology firm to provide the large firm with ways of augmenting its stock of knowledge and techniques. A deeper evaluation of firm-university collaborations' impacts on innovation is found in the following section.

2.4.2 University-industry collaborations

Firms are increasingly entering into collaborations with universities. This increase must, on the one hand, be seen be related to: i) The Bayh Dole Act (1980), making, at least in the US, universities more attractive partners and ii) insufficient governmental funding, making universities turn to industry for the extra funds. Consequently, universities are increasingly changing their approach and mission towards applied research (Santoro and Chakrabarti, 1999).

Although focusing on BioPharma firms partnering only, Atun *et al.* (2007) provide some insight into the current university-industry partnering trend.

By interviewing key informants both in firms and universities, Atun *et al.* (2007) not only find that the number of firm-university collaborations has increased significantly over the last decades but more interestingly, that the increase "has led to a wide range of variety of partnering arrangements" (p. 334) comprising a number of arrangements on partnering continuum, extending from arm's length in-licensing, consultancy services, contract research, collaborative research, joint venture arrangements, and including in-sourcing.

The above reveals more businesslike modes of collaboration. In fact, apart from the obvious exception of the equity based mode, the modes of collaborations found between them seem to be similar to those found in inter-firm collaborations (see section 2.4.1).

Although it is impossible to generalise beyond these findings, the question arises as to what the motivations are for shifting from a basic to an applied focus.

Saez *et al.* (2002) provide a deeper understanding of the motivations behind firm-university collaborations.

Building on theory, Saez *et al.* (2002) derive the following set of hypotheses from the literature: i) in line with the traditional view of university research, the first hypothesis proposes that collaborations with universities primarily are initiated to undertake basic knowledge; ii) building on previous findings that universities provide access to international knowledge networks, the second hypothesis postulates that universities will be motivated by the desire to improve their position in the international market; iii) the third hypothesis is that firms form collaborations in order to obtain funding.

Testing the hypotheses on a sample of 747 Spanish manufacturing firms, Saez *et al.* (2002) find support for all the hypotheses. Interestingly, the finding that it is firms that invest in basic research that seek to enter into collaborations with universities clearly lends support to the absorptive capacity argument.

In terms of the actual effects of collaborations on innovation, Atun *et al.* (2007) find that the collaborations between biopharmaceutical firms and universities increased innovation in all the relevant organisations' R&D and enhanced "the ability to find innovative solutions to problems".

Whilst insight into the positive effect of industry-university interactions on firms' innovative performance is found in Mansfield (1991), the interactions seem to be more 'loosely coupled'.

The aim of Mansfield's 1991 study is to reveal the extent of the impact of recent academic research on industrial innovation, and what the time lags are "between the investment in recent academic research projects and the industrial utilisation of their findings" (Mansfield, 1991, p. 1). To this aim, Mansfield (1991) obtained and analysed data from top R&D executives of a sample of 76 major American firms operating in seven different industries. In particular, data refer to the proportion of each firm's new products and processes commercialised in a given period of time that, "according to these executives [...] could not have been developed (without substantial delay) in the absence of academic research carried out within 15 years of the first introduction of the innovation." (Mansfield, 1991, p. 2).

Mansfield's (1991) main finding is that approximately one in ten new products and processes commercialised in a given period of time would not have "been developed (without substantial delay) without recent academic research." (Mansfield, 1991, p. 11). Also, a tentative finding is that the time lag between recent academic research and commercialisation of innovation is of approximately seven years. Hence, Mansfield's (1991) paper supports the assumption that academic research has a 'considerable' direct effect on industrial innovation, and this is particularly evident in three of the seven industries he investigated, including pharmaceuticals.

Recognising that there are potential benefits from knowledge transfer that extend beyond commercial exploitation, Bishop and D'este (2008) seek to investigate the deeper importance of firm-university collaboration for innovation. Building primarily on surveys including a sample of 478 questionnaires, they find: i) assistance in problem solving, ii) improved understanding and iii) sources of information for new projects as the most important benefits deriving from firms interactions with universities. Viewing these in the light of the absorptive capacity literature, they conclude that these benefits have direct

effects on the firms' learning capabilities, i.e.: explorative, exploitative and assimilation and transformation capabilities. In the light of this finding, it is important to note that personal contacts with university staff are regarded as among the most important benefits firms gain from universities (see Salter and Martin (2001) for a review).

The above reveals a clear congruence between firms' motivations for entering into collaborations with universities and their distinctive effects. Specifically, whilst a university collaboration is primarily initiated to undertake less targeted research, Atun *et al.* (2007), Mansfield and Bishop and D'este (2008) provide evidence that interaction has positive impacts on firms' innovative performance.

2.5 Complementarity between the knowledge acquisition strategies

Although the above sections 2.3 and 2.4 focus on the distinctive effects R&D and collaboration have on innovation, it is important to note that a growing strand of literature has started to focus on the complementary effects of internal and external R&D on innovation. The issue of complementarity is topical due to the stronger division of labour experienced in the drug industry (see section 1.1.3, chapter one). As such, whilst section 2.5.1 explores the literature on complementarity between internal and external R&D in detail, section 2.5.2 seeks to present the underlying reasons for the observed division of innovative labour taking place in the pharmaceutical industry.

2.5.1 Complementarity between internal and external R&D

As noted in Cassiman and Veuglers (2006), the literature on complementarity originates with the theory of supermodality. Translating this mathematical model into words, Cassiman and Veuglers (2006) denote the necessary conditions for activities to be

complementary in the following definition: "characteristics of two activities", whereby "adding one activity while the other activity is already being performed has a higher incremental effect on performance than adding the activity in isolation" (p.70). As suggested by its name, the higher incremental effect on performance obtained through complementarity is a result of firms gaining access to complementary expertise through carrying out different strategies.

Arora and Gambardella (1990) provide an elegant and effective illustration of complementarity in the introduction to their paper, showing how big pharmaceutical firms have actively engaged with different strategies with distinctive objectives, i.e. research and joint development agreements with other firms, research agreements with universities, investment in the capital stock of New Biotech Firms (i.e. NBFs) and acquisitions of NBF, as a means to enter into biotechnology. Specifically, Arora and Gambardella (1990) show that whilst most agreements with other firms tend to be product specific, most collaborations with universities focus on basic knowledge. However, although university relationships are motivated by gaining some familiarity with basic knowledge in biotechnology, they also provide pharmaceutical firms with the first option of licensing any discovery made by the collaborating university. Minority participations in capital stocks, on the other hand, are motivated by gaining some familiarity with the applied laboratory research skills of the NBFs as well as establishing a 'preferential link' to licence the NBFs' discoveries. Lastly, Arora and Gambardella (1990) claim that acquiring small NBFs is motivated by two partially contradictory motivations, whereby the large players either seek to acquire specific skills or to catch up. The latter is especially true when firms are relatively later entrants in a field. However, in both cases, the acquisitions are motivated by the firm's long term objectives.

Having not only seen that absorptive capacity depends on internal R&D in order to acquire and exploit knowledge from external sources – which in itself suggests complementarity – but also provided evidence for its effect on innovation (see section 2.3), it is interesting to note that the empirical literature specifically investigating complementary is not conclusive about either the effects of, or the source behind, complementarity. The remainder of this section seeks firstly to review empirical works to illustrate this mixed picture, then to present key works that provide some insight into the source of complementarity. In terms of the former point, the empirical literature reveals a mixed picture both between and within industries, including the pharmaceutical industry.

A paper with implications for complementarity effects between industries is Audretch *et al.* (1996). The aim of their research is to identify the factors that influence firms' decisions to engage in external R&D and internal R&D, to fill the gap of "the traditional literature on the knowledge production function [that] provides virtually no insight into this question" (Audretch *et al.,* 1996, p. 520). Hence, they address the question using institutional economics concepts, such as uncertainty, information asymmetries, asset specificity and the principal-agent relationship, based on which they build a model that links the various concepts together. The model is then applied to a sample of over one thousand Dutch firms with the aforementioned result that high tech firms tend to use both internal and external R&D, whilst low tech firms tend to use either internal or external R&D. The reason for these different behaviours is seen by Audretch *et al.* (1996) in the need for "critical mass", whereby "either the firm needs to develop a certain amount of R&D effort, or the firm needs to be in an environment with ample technological opportunities" (Audretch *et al.,* 1996, p. 528) in order to be able to engage in both internal and external R&D.

Audretch *et al.'s* (1996) finding that internal and external R&D are complements in high tech industry is sharply contrasted by Bloningen and Taylor (2000). Seeking specifically to investigate the relationship between R&D and technology acquisition in high tech industries, using a panel of 217 US electronic and electronical firms in the period 1985-1993, Bloningen and Taylor (2000) find a strong negative relationship between R&D and technology acquisition on both their dimensions of the data, i.e. 'across firms' and 'over time within a firm', providing evidence that "not only are relatively low R&D-intensive firms more likely to acquire, but over time a firm is more likely to acquire during periods of lower R&D intensity" (p. 49).

Focusing more generally on manufacturing firms, Bonte (2003), on the other hand, seeks to investigate "whether an increasing share of external in total R&D has a positive impact on the firms' growth or productivity" [... where] "production functions as well as TFP (Total Factor Productivity) equations are estimated where the share of external R&D is included as an additional variable" (p.344). Testing this using a panel of 26 West German manufacturing firms, his findings reveal a strong "positive relationship between productivity and the share of external R&D in total R&D" (p. 343). The fact that this particular finding includes both lower and higher tech industries stands in clear contrast to both Audretch *et al.* (1996) and Bloningen and Taylor (2000). Importantly, although a positive relationship is found, "the results imply a nonlinear relationship between internal and external R&D for higher-technology industries, hinting at decreasing productivity effects of an increasing share of external in total R&D" (p. 343). This particular finding, that external R&D only has productive effects up to a certain point for high tech industries, seems to provide a deeper insight into the reasons for the divergent picture of the complementarity effects found in the high tech industries.

Whilst Bonte's (2003) insight that complementarity effects decrease after a certain point is intriguing, more specific work on the pharmaceutical industry provides a still more mixed picture regarding the effects of complementarity. Analysing the impact of the number of R&D projects initiated in-house and under outsourcing, Fernandez-Bagues (2004) finds a negative relationship between 'make' and 'buy' strategies (in Lokshin *et al.*, 2008, p. 401). This particular finding stands in contrast with Gambardella and Arora (1990) who are not only among the first to test complementarity but also provide some insight into the source behind complementarity.

As indicated above, Gambardella and Arora (1990) seek to investigate complementarity between all the different strategies used by large firms to enter into biotechnology i.e. research and joint development agreements with other firms, research agreements with universities, investment in the capital stock of New Biotech Firms (i.e. NBFs) and acquisitions of NBFs. Due to the lack of data, Gambardella and Arora (1990) fail to test directly for complementarity. However, Gambardella and Arora (1990) find a positive correlation between all the different strategies even after correcting for a set of firm characteristics. Their findings show that to the contrary of what they expected a priori, it was the large firms with the higher internal knowledge (measured by number of patents) that were more actively involved in engaging in external linkages (p. 373). Although stressing the tentative nature of this particular finding, referring to the fact that patents do not capture 'all the dimensions of internal knowledge', Arora and Gambardella (1990) explain the finding by proposing that greater internal knowledge facilitates a better evaluation of the synergies with the knowledge base in the external environment (p. 374).

Given the intriguing results obtained in Arora and Gambardella (1990), Arora and Gambardella seek to investigate the relation between in-house capabilities and external R&D more rigorously in their subsequent 1994a paper.

Building directly on Rosenberg (1990) who sees in-house R&D as important, as it enables firms to evaluate the technological opportunities, and Cohen and Levinthal (1989) who hold in-house R&D as important to utilise external knowledge (see section 2.3.1.2 for more information), Arora and Gambardella (1994a) make a distinction between 'the ability to evaluate external opportunities' and 'the ability to use external knowledge' (i.e. absorptive capacity). Using publications as a proxy for the ability to evaluate external knowledge and patents as a proxy for the ability to use external knowledge, Arora and Gambardella (1994a) test the implications of the distinctive abilities for the firms' ability and the willingness to derive value from external linkages (p. 93) on a panel of 28 large US chemical and pharmaceutical firms active in the biotechnology sector. Their findings show that whilst the ability to utilize knowledge raises the number of innovation ventures, "firms with better ability to evaluate knowledge are more selective and focus on fewer but more valuable linkages" (pp. 108-109), they clearly prove that firms' abilities have implications for complementarity.

Whilst the above provides interesting insights into both the effects and the source of complementarity, more readily available data in recent years have enabled testing for complementarity and its sources more rigorously. Cassiman and Veuglers (2006) and Lokshin et al. (2008) are clear examples of this.

With regards to the development of data, Cassiman and Veuglers (2006) claim to be the first to develop an empirical method to systematically examine complementarity. Using a productivity (direct) approach and an adoption (indirect) approach, as well as a combination of the two, multinominal logit models allowed them to rigorously test both the existence of complementarity as well as to examine the effect of contextual sources on complementarity. The tests, carried out on a sample of 269 Dutch manufacturing firms, revealed not only that internal and external R&D are complementary innovation strategies

but they "identify reliance on basic R&D (i.e., "the use of universities and research centres as information sources), as an important contextual variable that influences the extent to which combining internal and external innovation activities increases a company's knowledge development potential" (p. 69). By emphasising the importance played by basic research, Cassiman and Veuglers's (2006) findings are in direct relation to Arora and Gambardella (1994a) but add to it the importance of universities.

Using a dynamic panel of 304 manufacturing firms in the period 1996-2001, Lokshin *et al's* (2008) findings show "complementarity between internal and external R&D in combination with decreasing returns to scale for both internal and external R&D. [Moreover,] a positive impact was only found conditional on a sufficient level of internal R&D expenditures" (p. 410). These findings, they claim, provide evidence for dual role of internal R&D and particularly the importance of the role absorptive capacity plays in complementarity.

2.5.2 Division of innovative labour

As seen under 'empirical motivation' in chapter one, the pharmaceutical industry is experiencing a clear division of innovative labour, with biotech firms and academia on one side and the pharmaceutical industry on the other; where academia and biotech firms have become specialised in drug discovery, whilst the pharmaceutical companies have become specialised in development and marketing of drugs (Arora and Gambardella, 1994b, Orsenigo *et al.*, 2006).

Division of labour was originally observed by Arora and Gambardella (1994b), who attributed it to the rise of more abstract and general knowledge. More specifically, whilst the innovation process before relied more on the use of tacit and firm specific capabilities,

the new advances both in technology and scientific understanding (e.g. in molecular biology and genetic engineering) have made it possible to separate the various sub-tasks within innovation processes for them to be reassembled later. This has enabled the various players to focus on tasks where they have their strongest capabilities.

Arora and Gambardella (1994b) refer directly to Arrow (1983) and Holmstrom (1989), who argue that small firms are more capable of carrying out novel and riskier innovation projects, whilst the large firms are more capable of carrying out large scale development, production and marketing. Arora and Gambardella (1994b) hence explain that the division of labour that the pharmaceutical industry is experiencing is one where the small firms focus their capabilities on the earlier stages of the innovation process and the large firms on the later stages. Arora and Gambardella (1994a) make the point that the 'downward capabilities of the innovation process' that characterise the capabilities of large firms are seen to depend on a slow and complex evolutionary process.

However, there is a wide debate in literature with regards to different organisational structures and sizes as determinants of firms' flexibility and ability to innovate. Smaller firms have the advantages of faster and more efficient communications among their members than the large ones, where the multitude of departments, branches and divisions requires their members to follow formal and longer communication channels. New ideas can be shared and evaluated more quickly in small firms than in the large ones, where new ideas must pass through several levels of authorisation and endorsement. Also, small firms benefit from less costly (albeit riskier) exit strategies, as their commitment to courses of action is naturally not as massive as in the case of larger firms, which put at stake huge investments every time they veer from a previous strategic choice. On the other hand, though, larger and wealthier firms' projects are unlikely to fail for lack of resources, given that the availability of capital is often more than needed for their completion. Larger firms

can also count on their ability to spread the risk of their projects, by embarking contextually on diverse portfolios of projects, enhancing the likelihood that at least some of them will be successful and will subsidise the others (Nooteboom, 2005). Pullen *et al.* (2009) point out that innovation is essential to the growth and survival of small and medium firms, but for the same reason, innovation becomes more challenging for these firms; e.g. their relative scarcity of resources may transform a simple delay in the completion of a project into a fatal mismatching of cash outflows and cash inflows. However, the view prevails that flexibility is *the* competitive advantage of small firms (Fiegenbaum and Karnani, 1991).

2.6 What is the practice of absorptive capacity?

Interestingly, despite a large volume of papers having used the concept of absorptive capacity since it was first introduced in 1989, only a few academics (e.g. Van den Bosch *et al.*, 1999; Lane and Lubatkin, 1998; Zahra and George, 2002) have sought to clarify the concept's components, processes and antecedents. The gap in the literature has been highlighted in the review paper on absorptive capacity (Lane *et al.* 2002 and 2006), as illustrated below.

"Most of [...] the studies that we reviewed used it [i.e. absorptive capacity] as a [...] catch-all-phrase to capture the internal dynamics of firms that relate to the acquisition, assimilation, or integration of knowledge. Reifying absorptive capacity and treating it as a distinct, integral something that the organization possesses has stagnated the development of this literature. It has resulted in little research examining the relationships which the construct was meant to capture: the process by which absorptive capacity is developed. This is very surprising because Cohen and Levinthal's view of the construct clearly encompassed the need to understand the dynamics within the organization that could lead

to the ability to recognize, assimilate and utilize useful external knowledge" (Lane *et al.*, 2002: 5)

Directly related to the limited understanding of the underlying processes behind absorptive capacity, Lane *et al.* (2002) argue that there has been little consensus among researchers of how to measure the concept, i.e. different researchers working from their own unique operationalisation of absorptive capacity. The variety of measurements is illustrated in this chapter, e.g. basic research, combinative capabilities, R&D spending, breadth of knowledge. As a consequence, the authors claim that absorptive capacity has become a term which is difficult to understand and to evaluate.

Interestingly, Lane *et al.* (2002) argue that the underlying reason for the gap in literature is due to the tacit nature of absorptive capacity. However, without any real efforts in investigating the processes behind absorptive capacity, this statement seems to be of a merely speculative nature.

2.7 Introduction to Zahra and George's framework and empirical work

Among the few that have sought to understand the nature of absorptive capacity, Zahra and George (2002) offer a theoretical model of the underlying processes of absorptive capacity and how they together produce a successful absorptive capacity. It is important to note that Zahra and George only provide a theoretical framework; they do not test it empirically. Their framework is introduced below.

As seen in section 2.3, Zahra and George (2002) view absorptive capacity as a dynamic capability (Teece *et al.*, 1997) and seek through their framework to illustrate how absorptive capacity fits this concept. Zahra and George's framework builds directly on

Cohen and Levinthal's (1989) definition of absorptive capacity, i.e. a firm's ability to identify, assimilate and exploit knowledge, but adds to it the role of 'transformation'. Together, these roles are presented as the various dimensions of absorptive capacity. Zahra and George (2002) see these dimensions, i.e. acquisition, assimilation, transformation and exploitation, as firm capabilities, building on organisational processes and routines, and suggest that it is by the four organisational capabilities building on each other that a firm obtains a "dynamic capability that influences the firm's ability to create and deploy the knowledge necessary to build other organisational capabilities" (p. 188) necessary for tackling changing environments. It is these diverse capabilities, they claim, that provide firms with competitive advantage and superior performance.

Critical for Zahra and George's (2002) theory is their concepts of 'potential absorptive capacity' (PACAP) and 'realised absorptive capacity' (RACAP). PACAP "comprises knowledge acquisition and assimilation capabilities", while RACAP "centres on transformation and exploitation" (p. 185). Though the two different absorptive capacities are interlinked and interact in an iterative way (and only by doing so can absorptive capacity become a dynamic capability), the two absorptive capacities perform different roles, i.e. PACAP functions more as an outward-looking absorptive capacity, whilst the RACAP can be compared to a more inward-looking absorptive capacity. By the two absorptive capacities working side by side, they resemble the concepts of explorative learning (Barkema and Vermeulen, 1998) and exploitative learning (Simonin, 1999).

A later study, carried out by Jansen *et al.* (2005) empirically validated the distinction between potential and realised absorptive capacity. Their more specific findings will be presented in the following section.

2.7.1 Practice of absorptive capacity

In addition to the fact that Zahra and George's model provides a theoretical starting point for understanding how absorptive capacity works, the empirical literature provides insight into factors that contribute to the development of specific aspects of absorptive capacity. By adding these more specific factors, including for example the findings obtained by Lane and Lubatkin (1998) (presented in section 2.3), to the theoretical framework developed by Zahra and George (2002), this section seeks to draw a picture of how absorptive capacity works. Using Zahra and George's framework as a theoretical starting point for this section, it is important to note that the first dimensions of absorptive capacity, i.e. acquisition and assimilation of knowledge, take form as 'potential absorptive capacity', while transformation and exploitation of knowledge comprise 'realised absorptive capacity'.

Potential absorptive capacity

- Acquisition of knowledge

As seen in section 2.2.1, at the same time as Cohen and Levinthal (1990) argue that learning is cumulative, they also highlight the importance of diversity of knowledge for innovation. The implications of these points for acquisition will be discussed below.

Firstly, as seen in section 2.4, Cohen and Levinthal's point of 'cumulative learning' is taken up by Lane and Lubatkin's (1998) research. Whilst initially proposing that by possessing some level of basic knowledge the firm is able to recognise and value external knowledge, Lane and Lubatkin (1998) actually find support for their hypothesis that a basic knowledge base enhances inter-organisational learning. The importance of basic research is further supported by several empirical works reviewed in this chapter, e.g. Cockburn and Henderson (1998).

Echoing Cohen and Levinthal (1990), Schmidt (2005) links the cumulative nature of knowledge to another determinant of absorptive capacity, i.e. individual absorptive capacities, stating that "the more education and training an employee receives, the higher his or her individual ability to acquire and use new knowledge will be". The importance of highly educated staff or champions for acquisition comes across clearly in the literature, illustrated both by Atun (2007) and Saez *et al.* (2002). In addition to emphasising the importance of highly educated staff, Devlin and Bleackley (1988) also highlight the importance of the size of the resources for a firm's ability to acquire knowledge.

Secondly, the importance attached to diversity should arguably lie at the heart of the motivation of *why* a firm would wish to acquire extramural knowledge in the first place. Evidence for this importance is illustrated in the section on complementarity literature, i.e. section 2.5. In addition to the obvious point that diversity makes the knowledge more difficult to acquire, the difficulty is, as seen in section 2.2, further enhanced by firm capabilities being based on sticky and tacit knowledge. As such, although the firm might have allocated a good number of highly educated staff to the environment, it is crucial to create the 'right' environment to ease the flow of 'sticky' information (e.g. Atun, 2007).

- Assimilation of knowledge

Interestingly, as noted in section 2.3.1, whilst Cohen and Levinthal in their 1990 paper emphasise that a firm's absorptive capacity depends on the firm's ability to transfer the new knowledge across and with the various subunits, they also stress that the firm's knowledge processes rely on a firm's tacit, i.e. firm specific, knowledge regarding its established systems for processing knowledge.

The former point has been taken up in many studies, i.e. whilst Van den Bosh et al. (1999) show that a firm's ability to assimilate knowledge is determined by its capacity to stimulate

knowledge sharing, Mahnke *et al.* (2005) and Jones and Craven (2001) provide evidence that the assimilation of knowledge can be encouraged through specific measures, i.e. forming workgroups made up of staff from different departments, introducing job rotation.

As seen in section 2.4, taking onboard the latter point that processing of knowledge is tacit and hence not observable, Lane and Lubatkin (1998) develop two proxies for the assimilation process: i) compensation practices and ii) organisational structure, arguing that the assimilation process will affect both. Interestingly, whilst Lane and Lubatkin (1998) find strong support for the role that similarities of compensation practices between the two collaborating firms have in inter-organisational learning, they find that only similarity of lower management formation and similarity of research centralization are positively correlated to inter-organisational learning. Looking more broadly at the literature, whilst Daugfoss (2004) and Welsch *et al.* (2001) find that organisational structure impacts on knowledge transfer, both Daugfoss (2004) and Mahnke *et al.* (2005) find that human resource management can stimulate a firm's knowledge building through reward systems and training.

Realised absorptive capacity

- Transformation of knowledge

Transformation is the dimension by which a firm realises how it can use the acquired knowledge for its own purposes, and must be the key dimension which has the potential to create new knowledge. With this as a potential, Nonaka and Takeutchi's (1994) model of knowledge creation seems highly applicable for a deeper understanding of this dimension.

At the core of their model, developed on the basis of case studies, Nonaka and Takeutchi (1994) argue that knowledge creation at the level of the organization is a result of making personal tacit knowledge explicit and disseminating this knowledge throughout the firm.

Nonaka and Takeutchi (1994) see the use of figurative language, redundancy and ambiguity as the key enablers for making tacit knowledge explicit.

It is important to note that although this model has received a lot of attention in the management literature, the process of making tacit knowledge explicit is a controversial view. One of critics, Tsoukas (2003), argues that as tacit knowledge is vectorial it is impossible that one can "focus on a set of particulars of tacit knowledge and turn it into explicit knowledge" (p. 122).

- Exploitation

As seen in section 2.4, both Lane and Lubatkin (1998) and Bishop and D'este (2008) provide some insights into the processes behind exploitation.

Interestingly, whilst Lane and Lubatkin find firms' own dominant logic, i.e. "a firm's preferences for projects of a given type, size, and risk level" (Grant (1988) in Lane and Lubatkin, 1998, p. 466) plays a crucial role for understanding how an idea can become commercially viable, Bishop and D'este (2008) find that firms obtain assistance with the issue of exploitation through collaborating with universities.

2.8 Research questions

As seen in section 2.3, Lane and Lubatkin (1998) extend the use of absorptive capacity, which Cohen and Levinthal (1989) present as a by-product of R&D, to collaborations and, as such, introduce a specific type of absorptive capacity that takes place between collaborating firms, which they call 'relative absorptive capacity'. The works of Cohen and Levinthal (1989, 1990 and 1994) and Lane and Lubatkin (1998) provide, as such, a theoretical basis for treating R&D and collaborations as distinctive knowledge strategies.

In light of the fact that innovation is the 'ultimate aim' of absorptive capacity (Lane *et al.*, 2002), the literature review has shown several empirical works that, building on a range of different measures, have sought to understand the effects absorptive capacity has on innovation, i.e. section 2.2. Furthermore, although relative capacity is a less frequently used concept, the importance of inter-organisational collaborations for innovation represents a popular strand of research, as seen in section 2.3. Yet another stream of research has focused more widely on the complementary effects of R&D and collaborations on innovation, i.e. section 2.4. However, despite the growing literature on the effects of R&D and collaborations on innovation, none of the reviewed research has investigated the distinctive effects of the different strategies. As such, by building on the works of Cohen and Levinthal (1989, 1990, 1994) and Lane and Lubatkin (1998) in addition to the idea that innovation processes build new capabilities (Leonard-Barton, 1995) this research seeks to provide insights into the effects of the different strategies on innovation and capability building, introducing the following research question:

Research question 1:

How important have the two key strategies identified by the AC literature (R&D and collaborations) been for pharma's ability to produce new drugs and to build innovative capabilities?

In addition to being highly topical due to the increase in pharmaceutical firms' R&D investment and number of collaborations, on the one hand, and the R&D inefficiency, on the other, the distinction between innovation and capacity building seeks to capture a deeper level of understanding of the importance the acquired knowledge has had for the firms, i.e. the extent to which it has allowed the firm to develop a single product or a more distinct firm capability.

As seen in section 2.6, although there is a defined gap in the literature regarding the understanding of the nature of absorptive capacity, the gap of the knowledge process extends to the collaboration literature, whereby the empirical literature has failed to provide insight into the factors that enable a firm to exploit knowledge from a collaborator. As a direct response to these gaps, research question two asks:

Research question 2:

'What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborators?'

In addition to the fact that an understanding of the knowledge processes underlying firms' abilities to acquire and exploit knowledge from collaborators represents a gap in the literature, the increasing number of collaborations that have taken place over the years in the pharmaceutical industry (see empirical motivation in chapter one) makes the research question highly topical.

As research question two is formulated, it adopts Zahra and George's (2002) theoretical framework for how absorptive capacity works, see section 2.6, and, as such, it frames the investigation of the knowledge processes that enable a firm to acquire and exploit knowledge. As mentioned in section 2.2.1, Lane and Lubatkin (1998) developed the term of 'relative absorptive capacity' for the type of absorptive capacity taking place in inter-organisational collaborations. Interestingly, whilst Lane and Lubatkin (1998) to some extent can be seen as 'foregoers' to Zahra and George as they viewed the dimensions found in Cohen and Levinthal's 1990 definition, i.e. recognise, value, assimilate and commercialise new knowledge as distinctive abilities, they also formulated specific hypotheses of which processes underlying the different abilities would contribute to inter-

organisational learning. However, they only focused on the relative factors that enabled a 'student firm' to learn from its 'teacher firm'. The insight obtained through their research provides not only insight into the question of *with whom* a learning alliance should be formed (p. 461) but also what factors contribute to inter-organisational learning more generally. Although this focus is an important issue, this research goes beyond the mere collaboration stage, focusing primarily on the student firm and how it *firstly acquires knowledge from a collaborator, then assimilates the acquired knowledge throughout the firm in order to transform and exploit it.* In this way, although the research involves the collaboration setting, the focus is on the firm as opposed to the 'relation' between the collaborating firm. As such, the theoretical focus of this research is hence closer to the original version of absorptive capacity (i.e. as presented by Cohen and Levinthal, 1989, 1990, 1994) than the concept of relative absorptive capacity, which then justifies the use of Zahra and George's framework for the investigation. However, by adopting Zahra and George's model for the research, this research seeks to focus the investigation on the specific processes and capabilities behind the different dimensions of absorptive capacity, i.e. knowledge acquisition, assimilation, transformation and exploitation. The attempt at identifying the specific factors that contribute to the various dimensions makes section 2.7.1 a sound starting point for the investigation of the key processes behind the various knowledge dimensions.

Building on the above, the research questions are as follows:

Research question one: '*How important have the two key strategies identified by the AC literature (**R&D and collaborations**) been for pharma's ability to produce new drugs and to build capabilities?*'

Research question two: *'What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborators?'*

Chapter 3:

Methodology

This chapter outlines the methodology of the research project. In doing so, it aims especially to provide insight into: i) how the research questions (3.1) as well as the epistemological stance of the research (3.2) have contributed to inform the choice of: overall research strategy (3.3), the units of analysis (3.4), choice of empirical sample (3.5), methods of *investigation* (3.6) and approach to analysis (3.7) and ii) how the conduct of the methods of investigation have sought to optimise the potential of the research questions and minimise the limitations associated with the research method. Section 3.8 addresses the chosen method's quality.

3.1 Research questions

As seen in chapter two, the works of Cohen and Levinthal (1989, 1990 and 1994) and Lane and Lubatkin (1998) provide a theoretical basis for treating R&D and collaborations as distinctive knowledge strategies, and for investigating their distinctive effects on innovation and capability building. This research question is particularly topical given the, on the one hand, exponential increase in R&D as well as a wave of collaborations and R&D taking place in the pharmaceutical industry over the years, and on the other, the R&D inefficiency (as seen in chapter one).

The second research question, on the other hand, is a direct result of the lack of understanding of the practice of absorptive capacity. Using a framework by Zahra and George (2002), research question two seeks to identify the key capabilities and processes that enable firms to *acquire, assimilate, transform and exploit* knowledge from collaborators.

The research questions are as follow:

1. '*How important have the two key strategies identified by the AC literature (R&D and collaborations) been for pharma's ability to produce new drugs and to build capabilities?*'

2. 'What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborators?'

3.2 Epistemological stance

"Epistemology is the study of the *nature of knowledge* – what counts as valid knowledge and how it can be gained" (Potter, 2006: 79). With reference to the development of a study's research methodology, Easterby-Smith *et al.* (1997) hold the benefits from exploring the different epistemological views in light of the research's objectives as follows:

- it assists the researcher to evaluate different methodologies and methods and avoid unnecessary work by identifying the limitations of particular approaches at an early stage.
- it helps refining the overall research strategy, including: the type of evidence to be gathered, the way in which such evidence should be interpreted, and how to answer the research questions posed.

3.2.1 Epistemological views

Three main epistemological views dominate the literature about the research process: positivism, constructivism and realism, whereby the positivism and constructivism are regarded as the more extreme ends of the spectrum. The different views will be discussed below in terms of their underlying ontology, i.e. 'the philosophy of reality'[2] as well as their associated methods of inquiry and research methods. It is important to note that although specific methods of inquiry generally are seen to follow specific epistemological views, several authors (e.g. Saunders *et al.*, 2003; Miles and Huberman, 1994) stress the methods of inquiry are not exclusively linked, and hence, the different methods of inquiry can be used in conjunction with any of the three epistemological traditions.

i) *Positivism*. "Positivist approaches to the social sciences assume things can be studied as hard facts and the relationship between these facts can be established as scientific laws. For positivists, such laws have the status of truth and social objects can be studied in much the same way as natural objects" (Smith, 1998). The quote presumes two distinctive features typically associated with positivism, i.e. *naïve realism* and *deduction*. i) *Naïve realism* is an ontology that assumes a one-to-one relationship between the external world and people's knowledge of it, and hence exerts that the reality they perceive is real (Potter, 2006; Christie *et al.*, 2000). The positivistic world is further seen operated by laws of cause of effect (Trochim, 2006) and, to understand it, reality must be reduced to discrete elements which can be recognised and classified (Christie *et al.*, 2000). ii) *A deductive method of inquiry* is typically associated with positivism, whereby hypotheses are postulated on the basis of theory and tested empirically (Saunders *et al*, 2003), and only when a hypothesis has been tested for verification does the theory obtain the status of a scientific law (Potter, 2006). The positivist approaches usually adopt quantitative methods

[2] Ontology is the philosophy about the nature of the world – what it consists of, what entities operate within it and how they interrelate to each other. Different ontologies make different assumptions (Potter, 2006).

that are outcome oriented and can allow for generalisations, e.g. surveys or statistics, and whereby the investigator can claim to stay completely detached from the object of study as the discoverer of the truth (Christie *et al.*, 2000).

ii) *Constructivism.* Whilst the positivists seek to uncover the truth, constructivists are critical of our ability to know the reality with certainty (Trochim, 2006). There are two elements to this sceptical view, both referring to the underlying ontology of constructivism, i.e. *critical realism.* The first element of critical realism refers to scepticism towards people's senses, and hence all observation is regarded as fallible (Trochim, 2006). The second element refers to the idea of social constructivism, i.e. the belief that reality is constructed and that people can construct a variety of different realities of the situations in which they find themselves, and as such constructivists reject the idea of a true and objective knowledge (Potter, 2006; Saunders *et al.*, 2003; Christie *et al.*, 2000). The belief that reality is being constructed makes the researcher within the constructivist tradition seek to understand the subjective reality of those that they study (Saunders *et al.*, 2003). This requires the researcher to become deeply involved in the study using qualitative methods. Due to the involvement required by the researcher, the constructivist researcher plays an active role in the creation of knowledge (Christie *et al.*, 2000) and hence, cannot achieve objectivity. Following the sceptical view of obtaining an objective truth, constructivists see all theories as biased. As such, an inductive approach by which data are collected and theory is developed as a result of this data, is usually associated with constructivism (Saunders *et al.*, 2003).

iii) *Realism*: In philosophical terms, realism could be regarded as a 'synthesis'[3] of positivism and constructivism, as illustrated by its underlying ontology, i.e. critical realism,

[3] Although Hegel never used the terms himself, the concepts: 'thesis', 'antithesis' and 'synthesis' are often used to describe his thoughts.

asserting that "reality is real but only probabilistically apprehensible" (Christie *et al.*, 2000: 9). The combination of positivistic and constructive influences are seen in the realist view of peoples' perception, i.e. although sharing its sceptical view of people's senses and their interpretations of the real mechanisms behind events with constructivists, realists still consider that perceptions provide a window to the external reality (Christie *et al.*, 2000). Hence, to overcome the limitations of our senses and obtain an increased understanding of reality, realism requires triangulation from many sources (Trochim, 2006; Christie *et al.*, 2000). As such, realism emphasises the importance of multi-methodological approaches and opens up to both qualitative and quantitative research methods. In a similar way as the realist view can be seen as a synthesis of positivism and constructivism, the method of inquiry, i.e. a retroductive approach, can be seen as the interplay between deduction and induction. The retroductive method of inquiry asks questions based on theory, and only by critically reflecting upon the data gathered, can the underlying theory be developed further.

3.2.2 Rationale for choosing Empirical Realism

This research positions itself within an empirical realist tradition, which is described by Bryman and Bell (2007), "as the most common form of realism, simply holding that through the use of appropriate methods, reality can be revealed" (p. 18).

By adopting a realist approach, the research, *per se*, directs scepticism towards the positivistic view that motivated the research (see chapter one) and, hence, urges a triangulation of methods for investigating the importance of the different knowledge acquisition strategies and the key processes beyond the various dimensions of absorptive capacity. A strength of realism is, however, that as it builds both on positivism and constructivism, an empirical realist approach opens up for the use of positivistic data as well as human social constructions, and hence can exploit the advantages of both. For

example, as positivistic views seek to uncover causal relationship, adopting a positivistic approach would be suitable for investigating the effects of the different knowledge acquisition strategies on innovative performance. A further strength of the realist approach is that it seeks to go beyond 'the first findings' through triangulating data, e.g. as per the example above, the findings regarding the effects of the different knowledge acquisition strategies obtained through the positivistic approach could be triangulated with people's perceptions of this relationship. Hence, as is the key for empirical realism, only by using the appropriate research methods and triangulating them will the research be able to uncover the nature of absorptive capacity and its effects.

3.3 Choice of research method: multiple case studies

The methodology chosen for this research project is 'multiple case studies', where each firm included in the project is held as a case study. Robson (2002) defines *case study* as: "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence" (p. 178).

This section seeks to provide the rationale for choosing a case study methodology (3.3.1) for this research but also to provide more general insight into the requirements for case methodology (3.3.2) as well as its limitations (3.3.3).

3.3.1 Rationale for choosing case study methodology and its research methods

The main strength of case-studies is held to be its suitability for including a multiplicity of methods (Yin, 1994). Hence, choosing a case study methodology for this research was assumed to fulfil the criterion, as set by empirical realism, regarding the use of multiple-

methodological approaches. However, to evaluate the applicability of using a case study methodology for this study, Yin's (1994) three criteria for choosing a research strategy were adopted: i) the types of questions posed, ii) the degree of focus on contemporary as opposed to historical events, and iii) the extent of control an investigator has over actual behavioural events. By evaluating the research according to these criteria, also the methods to be included in the case studies were identified and justified.

i) *The types of questions posed*

According to Yin (1994), case studies generally address *'why'* and *'how'* questions. As seen in 3.1, whilst the first research question starts with *'how'*, the second question starts with *'what'*. Given that the second research question is formulated with a question word that is not generally associated with case studies makes it even more important to discuss the nature of the research questions to argue for using case studies for this particular research.

The fact that *research question one* starts with 'how' provides initial grounds for suitability of case study. However, given that the aim of the research question is to investigate the distinctive effects of the different knowledge acquisition strategies, the research question could equally be formulated with 'what' effects. Hence, this question word can be interpreted as a 'how much what'.

As seen above, *research question two* seeks to investigate the different processes behind the dimensions of absorptive capacity. Given the lack of literature on the underlying processes and capabilities of absorptive capacity, the *'what'* found in this research question must be described as an explorative *'what'*. Yin (1994) stresses the applicability of using a case study methodology for explorative studies, as it – more than other research methods – opens up for numerous variables and aspects as the research unfolds and, as such, allows

more integrative perspectives of analysis, providing a deeper insight into the phenomena in question. In addition to the more general suitability of using case studies for explorative studies, the applicability of using case studies for research question two is further evident, with Hartley (1994) holding case studies as being particularly suitable for studying processes in organisations.

The above discussion not only gives a first basis for the applicability of using a case study methodology for this research, but also, by discussing the nature of the research questions, provides a first indication of suitable research methods. In regards to the latter, by referring to a basic classification scheme that identifies which questions are better investigated through the various research strategies, Yin (1994) holds that the different types of meanings of '*what*' questions imply different methodologies, i.e. whereas *'how-much-whats'* are better investigated through survey or archival analysis, the more explorative *'what'* in theory can be investigated using almost any method. Whilst the above has direct implications for the most suitable research methods for research question one, the identification of suitable research methods for research question two depends on further evaluation in regards to the following two criteria for choosing a research strategy, i.e. 'the degree of focus on contemporary as opposed to historical events' and 'the extent of control an investigator has over actual behavioural events'.

ii) *The degree of focus on contemporary as opposed to historical events.*

Whilst a case study methodology is primarily used to investigate contemporary phenomena, it is considered a suitable methodology as long as there is a living past, i.e. there are still relevant persons alive to report on the phenomena (Yin, 1994). As seen in 3.1, by seeking to investigate the effects of the different strategies as well as the key processes involved in acquiring, assimilating, transforming and exploiting knowledge from a collaborator, the research inevitably bears on the past. As seen in chapter one, however,

the big pharmaceutical firms did not actively seek to enter into biotechnology until the early 1990s (see section 1.1.1), and this research does not therefore intend to go beyond the scope of this time frame, which hence justifies the choice of case study. The challenges of doing retrospective research were, however, considered key when deciding the different research methods to be included in the case study for each of the research questions. Insight into the evaluation of the most suitable research method against this criterion for each of the research questions follows below.

Research question one. Given that archival analysis and surveys were identified as the most suitable methods for research question one, the evaluation of this second criterion started with assessing the strengths of these methods in investigating the past. By considering different ways by which these methods could be used to investigate research question one, it was concluded that, due to its reliance on quantitative data, archival data analysis would provide better reliability of phenomena. The conclusion was particularly based on the idea that by operationalising aspects of the research into quantitative measures, an archival analysis would not only allow the tracing of the reliance on strategies (R&D and collaboration) but also by using various measures of innovation would provide a basis to objectively investigate the effects of strategies on innovation. In addition to obtaining objective and hence reliable data, the use of quantitative measures would allow using standard measures, e.g. R&D intensity for absorptive capacity (Cohen and Levinthal, 1989, 1990), which would place this research in line with previous research. It is important to note that whilst an indication of the importance of the different strategies for both innovation and capability building would be captured by surveys, these would be merely perceptions rather than objective data.

Due to its objective data, archival analysis was regarded as the most suitable 'first method'. However, in order to be in line with the epistemological stance, it was also considered

crucial to carry out interviews to obtain employees' views on the research questions. Although it was recognised that this could be achieved by surveys, which then would have taken account of both the research methods identified in the evaluation of Yin's first criterion, semi-structured interviews were considered a more flexible and direct way to deepen the knowledge of the specific findings obtained through the archival data analysis. Besides, triangulating archival data, document analysis and interviews was assumed to correct their respective weaknesses, i.e. whilst conducting an archival data analysis prior to the semi-structured interviews was seen to enhance the ability to ask specific questions based on the firms' past, and hence increasing the respondents' recollection of events, obtaining the views of the interviewees, on the other hand, was seen to reduce bias stemming from poor selection and bias of authors (see table 1).

Research question two. Following the same logic as above, it was concluded that research question two would also benefit from relying on an 'objective first method'. However, due to a less quantitative emphasis when investigating processes and capabilities, the first method providing background for the development of an interview guide would rely on document analysis as opposed to archival data analysis. Although the document analysis was considered key for obtaining an insight into the key processes and capabilities behind the different types of absorptive capacity, an investigation into the processes and capabilities in firms was, however, highly dependent on a qualitative research method. In this regard, it is important to note that although it was recognised that participant observation has the potential to bring the researcher closer to the actual operations, and as such, the research would obtain a deeper insight into the key processes enabling a firm to acquire, assimilate, transform and exploit knowledge from a collaborator, constraints such as of time made semi-structured interviews the most appropriate choice. Table 3.1 summarises the above discussion showing the strengths and weaknesses of the research methods under consideration.

Table 3.1: Strength and weaknesses associated with suitable research methods

Source of evidence	Strengths	Weaknesses
Documentation	- Stable – can be reviewed repeatedly - Unobtrusive – not created as a result of the case study - Exact – contains exact names, references, and details of an event - Broad coverage – long span of time, many events, and many settings	- Retrievability – can be low - Biased selectivity, if collection is incomplete - Reporting bias – reflects (unknown) bias of author - Access – may be deliberately blocked
Archival records	- Same as above - Precise and quantitative	- Same as above - Accessibility due to privacy reasons
Interviews	- Targeted – focuses directly on case study topic - Insightful – provides perceived causal inferences	- Bias due to poorly constructed questions - Response bias - Inaccuracies due to poor recall - Reflexivity – interviewee gives what interviewer wants to hear
Participant observation	- Reality – covers events in real time - Contextual – covers context of events - Insightful into interpersonal behaviour and motives	- Time consuming - Selectivity – unless broad coverage - Reflexitivity - Cost – hours needed by human observers

Source: adapted from Yin (2009)

iii) *'The extent of control an investigator has over actual behavioural events.*

As seen above, the fact that behavioural events had taken place in the past means that the investigator has no control over them, which is a precondition for case studies. In addition to this, by triangulating the research methods archival data analysis, document analysis and semi-structured interviews, the research was assumed to obtain a more objective knowledge of the phenomena, leaving less scope for the researcher's own interpretations.

3.3.2 Applying a case study methodology

Yin (1994) holds theory to be essential for a case study methodology, forming all the components of the research design, i.e.: i) a study's questions, ii) its propositions, if any, iii) its unit(s) of analysis, iv) the logic linking the data to the propositions, and v) the criteria for interpreting the findings. By basing the research design on theory, the theory

further guides the research in more practical regards by keeping the study within feasible limits and by deciding what kind of data to collect.

The importance of theory in the design of case study methodology is clearly in line with the retroductive approach adopted by the research (3.2.1), which holds that only by informing the research on the basis of theory can the research offer theory development. The main theory selected/adopted for this research is absorptive capacity.

3.3.3 Limitations of case studies

Although multiple case studies are seen to be the most suitable choice for this study, it is important to understand the general limitations associated with case study methodology, as effective measures can be taken to minimise the scope of these limitations through a thorough planning of the research.

Yin (1994) summarises the limitations by stating that apart from requiring thorough preparation and being time consuming, case studies are seen to:

i) lack academic rigour, either because the investigator fails to develop a sufficiently operational set of measures and/or has allowed equivocal evidence or biased views to influence the direction of the findings,

ii) provide little basis for scientific generalisation,

iii) produce massive unreadable documents.

This will be addressed in section 3.6 methods of investigation.

3.4 The units of analysis

The units of analysis draw the boundaries of the research.

As seen in section 3.1, given that both the research questions focus on pharma, i.e. research question one seeks to investigate the distinctive importance R&D and collaborations have had for pharma's innovation and capability building, and research question two seeks to identify the key processes that enable big pharma to acquire, assimilate, transform and exploit knowledge, the unit of analysis is the 'firm'. It is, however, important to note that, given that the firm acquires knowledge from collaborators, the unit of analysis in research question 2 includes collaborative links.

Figures 3.1 and 3.2 provide a simplified illustration of the units of the research. Figure 3.1 illustrates that firm X has the ability to acquire knowledge from the environment and that this acquired knowledge has the potential to create new innovation (which, according to Leonard-Barton (1995), gives rise to capability building). Figure 3.2 shows that a firm can acquire extramural knowledge through a collaboration with external organisation Y (firm or university), either directly or through a co-development. The second objective of the research is to investigate the key processes that enable a firm involved in acquiring, assimilating, transforming and exploiting extramural knowledge from a firm (i.e. biotech firm).

Figure 3.1: R&D as a knowledge acquisition strategy

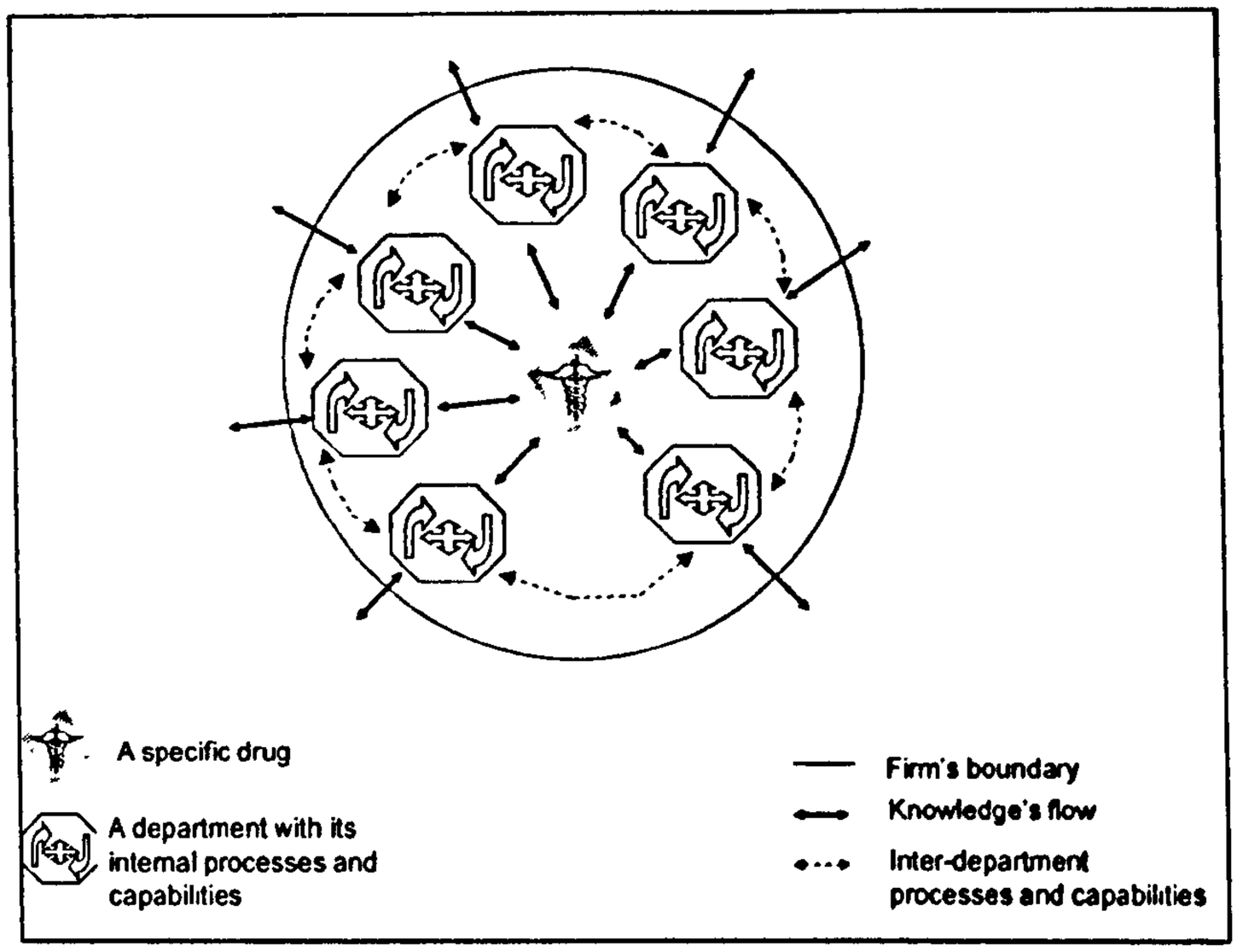
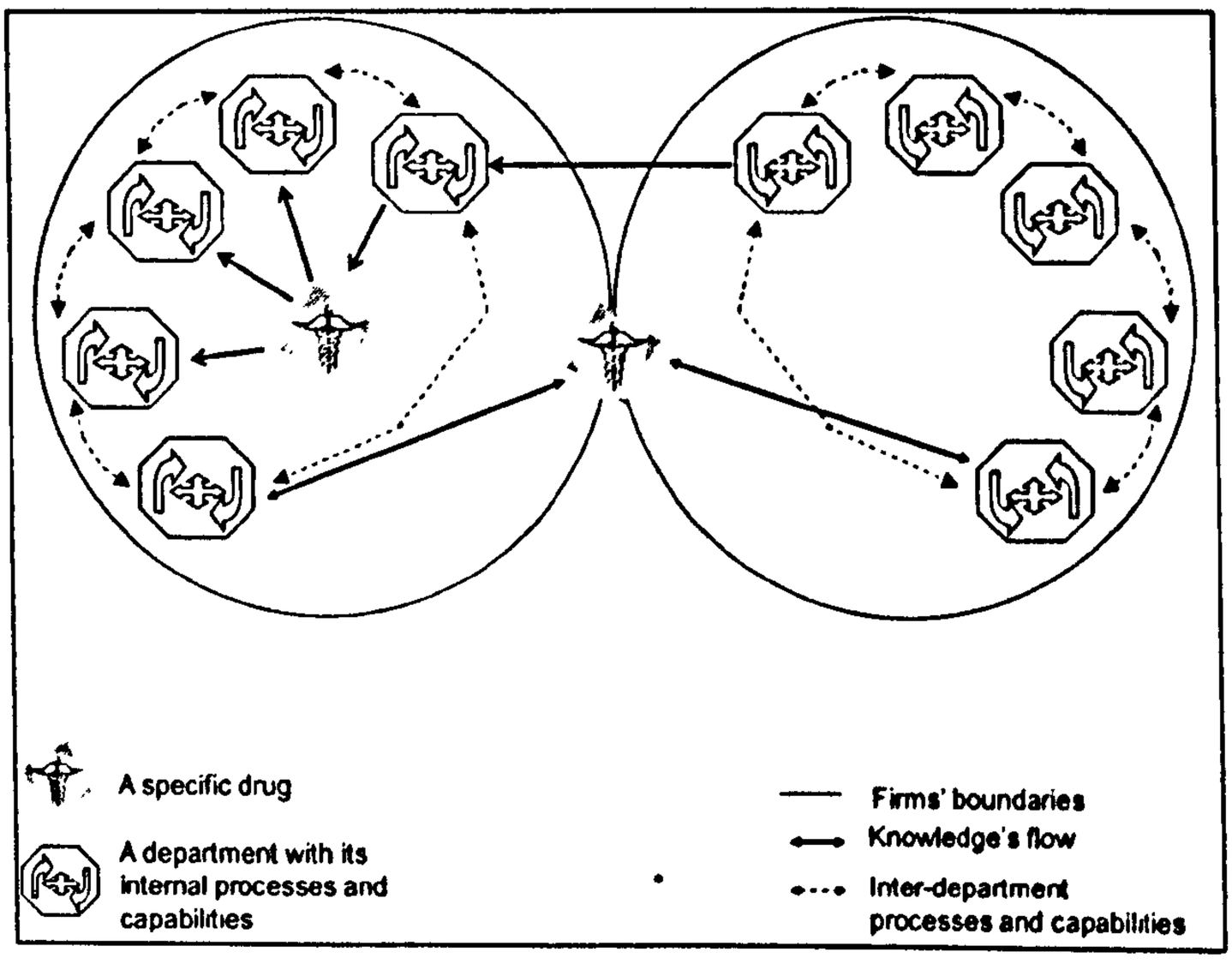


Figure 3.2: Collaboration as a knowledge acquisition strategy



3.5 The choice of empirical sample

According to Bryman and Bell (2007), to gain a deeper understanding of the cases as well as facilitate the development of an analytical frame and concepts used in the research, the researcher should find a suitable population to study.

As seen in section 3.1, the research questions were framed with large pharmaceutical firms in mind. To recap, it was the fact that big pharma, on the one hand, has exponentially increased its investment in R&D and number of collaborations over the new knowledge regime, and, on the other hand, is suffering a current R&D inefficiency, which together shows a reverse picture to that which is theoretically expected. This inspired an investigation into the effects of the different knowledge acquisition strategies as well as the key processes involved in successful knowledge acquisition (see chapter one). Though framed on big pharmaceutical firms, the remainder of this section seeks to provide insight into the optimal sample size to enhance the investigation of the research questions.

- Research Question 1

In order to obtain a better understanding of the importance played by R&D and collaboration for innovation and capability building, it seemed crucial to carry out an investigation of more than one firm. However, in order to ensure a deep investigation into the phenomena, it was considered feasible to carry out an investigation on no more than three large firms. Though a low number, carrying out a multiple case study on three firms would allow comparison of the findings across the cases.

In order to obtain a deeper understanding of the distinctive importance of R&D and collaboration, it was considered important to carry out yet further interviews with 'industry experts' and then particularly Consultants and University Professors.

- Research Question 2

Although the key focus of the investigation of research question 2 is on big pharma, it was regarded crucial to include the collaborating firm into the empirical sample. Including a pair of collaborating firms was assumed to provide a richer insight into the processes behind different knowledge, as this would give the opportunity to investigate both 'sides' of the collaboration and the knowledge exchanges between the two, hence making an effective triangulation possible. Despite being small, the sample size was considered appropriate in order to obtain the richest possible insight into the phenomena whilst keeping the research within a feasible limit.

Interestingly, the identification of a collaboration suitable for research question two was obtained through the document analysis carried out as part of the investigation of research question one, i.e. going through the collaboration history of the sample firms, the researcher came to learn that one of the firms had sought to form large scale collaborations with small biotech firms as means to enter into Monoclonal Antibodies (MAbs). Although the focus of the case study was to investigate the key knowledge processes enabling this big pharma firm to acquire, assimilate, transform and exploit the smaller firm's knowledge, it would also prove to provide in-depth understanding of the specific effects collaborations have on the firm's innovative capabilities. As such, whilst a suitable sample for research question two was identified through the investigation of research question one, this empirical sample would provide an illustrative case also for research question one.

Furthermore, although the investigation of research question two relied primarily on the case study, the fact that semi-structured interviews were used to investigate research question one laid a basis for piloting the investigation of research question two.

3.5.1 Negotiation of access

Given that a qualitative research method (i.e. semi-structured interviews) was identified as one of the most suitable research methods for both the research questions (see section 3.3.1), it remained necessary to negotiate access to suitable pharmaceutical firms in order to obtain access to interviewees. Given that the research, as a starting point, could investigate any of the top pharmaceutical firms, the researcher used her own network to establish some initial contacts with representatives at some of these firms. In all the cases, these contacts were all part of the top management teams, including a CEO. Having had the opportunity face-to-face, the researcher sent a further letter explaining the objectives of the research. Eventually access was granted in three of the top pharmaceutical firms. Although research question two was piloted in all the firms, the principal investigation of the key processes that enabled a firm to acquire, assimilate, transform and exploit knowledge from collaborators was carried out on one of the sample firms as it had used collaborations with external partners as means to enter into MAbs. In this context, it is important to note that given that one of the collaborating firms had been acquired by the big pharmaceutical company by the time the research took place, the researcher also had the opportunity to carry out interviews in one of the collaborating firms. Hence, having been granted access to the big pharma firm as a whole then meant that the researcher also had access to those representatives that had belonged to that smaller firm.

3.6 Methods of investigation

As seen above (section 3.3), the research relies on multiple case studies, including archival analysis, document analysis and semi-structured interviews. The following paragraphs seek to address how the different research methods and their execution optimise the potential of the research questions, enhance the reliability and validity of the research as well as minimise the scope of the limitations associated with the overall case study methodology.

Table 3.2: Overview of the research methods and type of data to be collected for the research questions

Research question	Method 1	Method 2	Data
1	Archival data analysis	Semi-structured interviews	Method 1 provides positivistic data by operationalising firms' knowledge acquisition strategies and performance into quantitative measures. By comparing the various measures, the research obtains quantitative pictures of the causal relationship between the different knowledge acquisition strategies and firm performance. The findings are triangulated with qualitative data obtained through method 2.
2	Document analysis	Semi-structured interviews	Method 1 provides insight into the key processes and capabilities behind the different dimensions of the different types of absorptive capacity. Although the data form a basis for triangulating the data from method 2, method 2 is considered to play a key role in the investigation.

3.6.1 Archival and data analysis

As seen in section 3.3, archival analysis and document analysis were respectively identified as the most suitable 'first methods' for research questions one and two.

The key methodological advantages associated with carrying out archival and document analysis prior to the interview in this research were the following:

i) providing an objective insight into the research questions, which would lead to and inform specific questions for the respective firms;

ii) asking specific and probing questions based on documentary evidence of the firm in question, was assumed to make the interview a more interesting experience, increase the respondents' understanding of the interview question as well as elicit their memory of what has happened in the past and, as such, prevent bias and increase the reliability and the validity of the research;

iii) in all, document analysis is seen as a way to augment the evidence for the research (Yin, 2003).

The remainder of this section seeks to provide a deeper understanding of the type of documents and data that were included for each of the research questions, as well as how the distinctive methods of analysis will be carried out to achieve the above advantages.

Research question one. '*How important have the two key strategies identified by the AC literature (**R&D and collaborations**) been for pharma's ability to produce new drugs and to build capabilities?*'

The crucial first step for using an archival data analysis to investigate the effects of the selected firms' knowledge acquisition strategies was to operationalise all the elements of the research question into quantitative measures, i.e. knowledge acquisition strategies, innovation and capabilities, using a wide range of sources. Given readily available data, the research also gathered data on related measures, i.e. number of M&As and various measures of economic performance. Including data on related measures was intended to provide a fuller picture of the selected firms.

<u>Overview of key measures</u>

- Knowledge acquisition strategies

  i) R&D was measured by R&D spending and R&D intensity. As seen in section 2.3.1.1, the latter is the most classic measurement of absorptive capacity, introduced by Cohen and Levinthal (1989). R&D data was obtained from S&P 500, Bloomberg and company records.

  ii) Number of Collaborations. The number of the R&D collaborations with universities and firms was traced from company records. Following Henderson and Clark (1990), the number of R&D collaborations was also measured as a number of co-authored publications between scientists of the selected firms with other scientists in external institutions. The latter method was seen to be particularly

suitable for measuring firms' R&D collaboration with universities and other big pharmaceutical firms. Publications data was obtained from ISI web of knowledge.

iii) Number of M&As. The number of M&As was taken from company records.

- Innovation was measured, using the following indicators

i) Number of total patents was held as an indication of inventive activity. Building on Demirel (2008), the ability to file at least one patent every third year was held as a measure for firms' innovation.

ii) Number of biotech patents, measuring the firms' ability to adapt to the new regime. All the patent data was obtained from Derwent.

iii) Number of drugs. Whilst number of patents was used as a proxy of inventive activity, the number of drugs was regarded as firms' actual ability to innovate. The number of drugs was obtained from company records

- Firm capabilities

i) Number of drugs company records. In light of the theoretical assertion that innovation is the prime engine for capability building, drugs were in addition to innovation also measures for capabilities.

- Economic performance was measured, using the following measures

i) Growth is measuring the firms' increase in volume of revenue. Revenue data was obtained from company records, Bloomberg and S&P data.

ii) Market value, measuring the appreciation by the market, was obtained from Nasdaq.

By operationalising the elements of the research question one into quantitative measures, these measures could then be traced over time for each of the selected firms and, as such,

provide quantitative pictures of the firms' reliance on the different knowledge acquisition strategies and their innovative and economic performance. Having obtained a full picture of all the different measures over time for each of the firms, it was possible to look for trends and compare the different knowledge acquisition strategies with the different measures of economic and innovative performance for each of the firms included in the research. As was intended, by analysing the trends of the different quantitative measures, the research obtained a first insight into how the different knowledge acquisition strategies distinctively have affected the firms' performance. However, as expected, the quantitative analysis gave rise to puzzles and questions, which were addressed and followed up in the interviews for confirmation and further exploration.

Research question 2. 'What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborating biotech firms?'

Given the assumption that document analyses could provide objective first insights, the researcher went to great lengths seeking to identify documents that could provide insight into the processes and capabilities that would enable a firm to 'acquire', 'assimilate', 'transform' and 'exploit' knowledge from a collaborator. In addition to documents that would address the firm's approaches to integrating knowledge from collaborators and how to carry them out, there was an expectation that there would be more specific documents on HR policies that would indicate the firm's approach to knowledge sharing through the use of incentives, job rota and cross-functional teams etc. Though some insights were obtained, the document analysis provided more general information on the collaborations the firm in question used to move into MAbs, i.e. their duration, aims, success, operations. The latter information was crucial background information, which allowed the researcher to ask specific and probing questions, based on documentary evidence, both on the key

processes involved in the knowledge exchanges and on the effects of the collaborations (see section 3.5).

3.6.2 Semi-structured interviews

Semi-structured interviews take place when "the researcher has a list of fairly specific topics to be covered, often referred to as an interview guide, but the interviewee has a great deal of leeway in how to reply" (Bryman and Bell, 2007: 474).

The rationale for carrying out semi-structured interviews for this research is threefold:

i) the fact that semi-structured interviews open up to the potential for follow-up questions allowed the interviews to focus on the role of the interviewees, and as such, explore the interviewees' specific knowledge. For example, whilst an interview with a scientist focused more on the key processes that enable the scientists to acquire, assimilate, transform and exploit knowledge from a collaborator, an interview with an accountant focused more on how the different types of absorptive capacity have contributed to the overall economic performance of the firm.

ii) similar to the previous point, the fact that semi-structured interviews allowed the interviewees room to pursue topics which are of their interest was considered an important aspect of the research, as these topics might contribute to new insights and hence to a deeper understanding of the research questions.

iii) despite the flexibility for both the researcher and interviewee, the structure of the semi-structured interview makes a cross case and or cross-interviews comparability among the firms possible.

Having provided the rationale for using semi-structured interviews, this section seeks to provide insight into the methodological choices taken in terms of: i) conduct of interviews, ii) challenges related to carrying out interviews and iii) handling of interview data.

i) Conduct of interviews[4]

Although all the interviewees had received emails explaining the research, the interview still started with a brief introduction into the objectives of the research and reassurances of anonymity.

Importantly, although research question two was specifically aimed at investigating the specific collaborations that a firm X had used to enter into a new area (see section 3.5), both research questions were investigated in all the interviews. Though some of the questions could be hypothetical for some, the reason for doing this was to obtain as many perspectives as possible on both the research questions.

In order for all the interviewees to be able to respond, the investigation of both of the research questions started by asking open-ended interview questions, e.g. how important do you think R&D and collaborations are in acquiring knowledge, do you think this emphasis has changed over time, what do you think are the key processes for acquiring knowledge from a collaborator?

Having obtained answers to these general questions, more detailed follow-up questions were introduced. The follow-up questions were often connected to interviewees' roles, e.g. whilst senior managers were likely to know more about the distinctive effects of the different knowledge acquisition strategies, scientists would be more inclined to know about the key processes enabling a firm to acquire, assimilate, transform and exploit knowledge

[4] Interview guide and interviewee list in appendices B and C

from a collaborator. In this way, although covering the key questions, the researcher would use the semi-structured interviews actively to allow for a deeper understanding of the phenomena.

Although adjusting interview questions to the roles of interviewees was important to obtain a deeper understanding of phenomena, the specific follow-up questions were also constructed on the basis of the investigation taking place prior to the interview. The investigation into the importance of the different knowledge acquisition strategies for innovation and capability (i.e. research question one) depended to a large degree on the findings obtained in the archival data analysis. As seen in section 3.6.1, the quantitative picture of the different knowledge acquisition strategies and the different measures of performance was assumed to inspire questions that would reveal a deeper understanding of the phenomena. In terms of research question two, the fact that there was little insight into specific processes was gained through the document analysis, the follow-up questions sought to cover specific findings from the literature instead.

It is important to note that the interviewees were identified through a snow-ball technique (Biernacki and Waldorf, 1981), where one interviewee would identify the next suitable interviewee and so on.

ii) Reflections on challenges and measures to meet them

Carrying out interviews on a topic which contains such commercially-sensitive information as how firms' competitive knowledge is being absorbed and exploited and what impact the different knowledge acquisition strategies have on performance, not only seemed challenging but also raised great concern as to whether the interviewees would share their views. Somewhat surprisingly, this actually turned out to be less of a problem than initially thought. Although it is difficult to pin down a specific reason this could be related to the

fact that the researcher guaranteed in all the written outputs, that all the individuals and the firms would be anonymous. Also, by gaining the confidence of the senior management, the senior management did not discourage staff from answering questions.

The other challenge was related to the fact that whilst some of the interviews were carried out on firm sites, some of the interviews were conducted over the phone. In order to compensate for the disadvantages of carrying out telephone interviews, the researcher prepared the material in great detail prior to each interview.

iii) Handling interview data

All the interviews were digitally recorded (audio only) although notes were taken throughout the interview. Also, after each interview was finished, the researcher wrote down brief minutes to summarise the main findings (Miles and Huberman, 1994). Brief summaries of key findings were not only considered to be a practical way to highlight the most important issues for future analysis but also served to counteract the common limitation of case studies, i.e. the production of massive unreadable documents. A summary of key findings was also used to limit the amount of errors etc, hence increasing both the reliability and the validity of the findings. In addition to the production of summaries of key findings, the interviews were transcribed in full. All the evidence regarding the cases was collected in a case study database to ease the analysis and enhance the reliability. Key informants were further asked to review the draft case study report to enhance construct validity.

3.7 Approach to data analysis

This section seeks to inform about the different types of analysis used in the research.

3.7.1 Within-case analysis

As seen in section 3.6, all the cases provided insight into both the research questions. How the research questions were analysed is explained below in terms of: i) how the analysis instruments applied to the research questions were derived, ii) the importance of each of the methods for the data analysis, and iii) how data from the different methods were triangulated.

Research question one. '*How important have the two key strategies identified by the AC literature (R&D and collaborations) been for pharma's ability to produce new drugs and to build capabilities?*'

As seen above, the key of the research question is to identify the distinctive effects of the different knowledge acquisition strategies. To recap, whilst several empirical works have confirmed the importance of R&D and collaboration for acquiring knowledge and hence its positive impact on innovation, the specific contribution of this research question was to investigate the distinctive impacts of the different strategies.

The clear aim of identifying the specific impacts associated with the different knowledge acquisition strategies made the quantitative data obtained through archival data particularly important. The archival analysis followed two distinctive analyses, as explained below.

Analysis 1:

The first-level analysis signifies the first step of the quantitative analysis as it operationalises the different knowledge acquisition strategies, innovation and economic performance into quantitative measures. By plotting quantitative data of these different measures, the first level analysis provides a picture of how the firms' reliance on the different knowledge acquisition strategies, their innovative capabilities and their economic performance have changed over time.

Analysis 2:

The second level-analysis, on the other hand, builds and elaborates on the first-level analysis, as it uses ratios as well as tracing the origins of the drugs to understand the importance of the different knowledge acquisition strategies for the various firms' innovative success. The latter was considered to provide the ultimate evidence for the distinctive effects of the different knowledge acquisition strategies.

Although the analysis of the first research question drew heavily on the archival data to provide insight into the actual effects of different knowledge acquisition strategies, the specific findings obtained were cross-checked with the interview data. In addition to this, only through the interviews could the research obtain an understanding of the underlying reasons for the findings. The triangulation therefore relied on both the methods but also on the answers from the various employees of the same firm.

Research question two. '*What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborators?*'

Given the lack of theory on the processes and capabilities behind the different dimensions of absorptive capacity, the analytical instrument for research question two followed directly from section 2.7, which explicitly sought to allocate general theories as well as specific empirical findings to the different dimensions of absorptive capacity to provide a priori understanding of the phenomena.

The advantage of having an analytical instrument that provided an a priori understanding of the key processes underlying the various dimensions of absorptive capacity was that it served as a yardstick to compare the findings deriving from the research with previous research and to identify new findings. Given that little insight into the key processes came from the document analysis, the investigation into research question two relied primarily on interview data. Triangulation was hence obtained through cross-checking the answers from the various employees both within and between the collaborating firms.

3.7.2 Cross-case analysis

Insight into the different approaches for analysis adopted by the research follows below.

Researach question one. Due to the fact that the investigation of research question one relied on three cases (see section 3.5), a cross-case analysis was crucial for research question one. Having carried out the same quantitative analyses (i.e. analysis 1 and analysis 2, see section 3.7.1) on all the cases, the cross-sectional analysis simply sought to look for trends between the cases. Interestingly, the fact that the results of the cross-case analysis were so similar meant that the interview data could be used to provide a deeper insight into the cross-sectional analysis as a whole rather than just the single cases.

Research question two. Although the investigation of research question two, as a starting point, relied on a single case only, the fact that research question two had been investigated in all the interviews made a cross-case analysis necessary also for research question two. Combining the findings of the in-depth case study and the 'more general' interviews had clear methodological advantages, i.e. whilst the case study provided deep insights into the key processes, the more general answers allowed the research to test the generality of the findings obtained through the case study.

3.8 Case study quality

Table 3.3 presents a summary of the different tests proposed by Yin (2009) to evaluate a case study's quality, including their explanations and the recommended case study tactics to be undertaken at the different phases of the research. The table below shows the measures that were taken in this particular research to improve the case study quality.

Table 3.3: Measures to test case study quality

Test	Explanation	Case study tactic	Phase of research
Construct validity	Establishing correct operational measures for the concepts being studied	- use multiple sources of evidence - establish chain of evidence - have key informants review draft case study report	- data collection - data collection - data collection
Internal validity	Establishing a causal relationship	- do pattern-matching	- data analysis
External validity	Establishing the domain to which a study's findings can be generalised	- use replication logic in multiple-case studies	- research design
Reliability	Demonstrating that the operations of a study can be repeated, with the same results	- use case study protocol - develop case study database	- data collection - data collection

Source: Yin (2009)

- Construct validity

The construct validity is assumed met for the following reasons: i) the elements of research question one were operationalised into appropriate measures, i.e. R&D spending, number of collaborations and M&As, growth, number of patents and number of drugs. Also, several of the measures derived from the literature; ii) the research used several methods, from which the findings could be triangulated and, as such, the research established a chain of evidence; iii) and as a last point, key informants were asked to review the draft case study report.

- External validity

Although the cases followed a replication logic, the sample size was still small and hence this multiple case study research cannot claim an external validity or generalizability. However, as the research has generated a deeper insight into both i) the idiosyncratic nature of absorptive capacity by building upon existing literature, through identifying both the most important processes and capabilities behind the dimensions of the different types of absorptive capacity, as well as identifying key routines and processes that have been neglected in the extant literature, and ii) the distinctive importance of the different knowledge acquisition strategies for innovation and capability, the research will claim a degree of theoretical generalizability.

- Reliability

In addition to making all the steps of the research explicit, the specific measure of case study database was taken to increase the 'replicability' of the research.

3.9 Summary and presentation of findings

The investigation of research question one, i.e. how important R&D and collaboration are for innovation and capability building, is based on a multiple case study on three top pharmaceutical firms, where each case relied on a triangulation between archival analysis and semi-structured interviews. As seen in section 3.5, the rationale for carrying out a case study on three firms was to allow comparison. In this context, it is key to note that whilst there was an initial expectation that the findings obtained could be of such firm specific character they would need to be presented case by case, the cross-case analysis revealed to the contrary such similar insights that it was possible to present only the specific findings obtained through the archival analysis case by case and then use the qualitative findings to advance on this understanding. Importantly, by presenting the findings in this way, the specific findings obtained through the different methods will be presented in separate chapters, i.e. whilst the findings obtained quantitative data analysis of the chosen firms will be presented in chapters 4, the findings from the semi-structured interviews will be presented in chapter 5.

The investigation of research question two, on the other hand, relied both on the semi-structured interviews carried out as part of the multiple case study and on an in-depth case study of two large scale collaborations, which one of the selected firms had formed as a means to acquire knowledge and develop capabilities in a new area (i.e. MAbs). As seen in section 3.5, the rationale for carrying out an in-depth case study was that its context exactly reflected the research question and, as such, gave a clearer reference for the interviews than did the more 'general interviews' carried out across the firms. There was also a realisation that by carrying out an in-depth case study on collaborations designed as means to enter into a new area, the case study would provide the research with a unique setting to investigate the actual effects collaborations have had on the firm's innovation and capability building and, hence, provide a deeper understanding of research question 1. It is

important to note that whilst the interviews carried out in the multiple case study were more general in nature, their findings allow the researcher to compare the findings obtained in the in-depth case study and hence to understand their generality (see section 3.5). However, given that the insights obtained from the multiple case studies was regarded merely as a pilot study for research question two, it will be presented at the end of chapter 5, whilst the in-depth case study will be presented in its entirety in chapter 6.

Chapter 4:

The importance played by R&D and collaboration for innovation and capability building - a quantitative analysis

4.1 Introduction

As seen in the methodology chapter, an archival analysis was conducted to provide first insight into the distinctive importance played by R&D and collaborations for innovation and capability building. In light of the fact that the archival analysis was carried out on each firm, allowing each firm to be compared, this chapter seeks to present the specific findings obtained for each of the selected firms in section 4.2, and the specific trends found in the cross-case analysis in section 4.3.

It is important to note that although the archival analysis has been carried out to provide an understanding of research question one, the extensive insights obtained in the archival analysis provide a larger context for evaluating the effects of the collaborations in the case study (presented in chapter 6).

4.2 Quantitative profiles of selected firms

The presentation of the quantitative profiles of the selected firms follows the two-level analysis designed to quantitatively investigate the distinctive importance R&D and collaborations play for innovation and capability building.

As seen in section 3.7.2, the first-level analysis sought to operationalise the different knowledge acquisition strategies, innovation and economic performance into quantitative measures. By plotting quantitative data of these different measures, the first-level analysis provides a picture of how the firms' reliance on the different knowledge acquisition strategies, their innovative capabilities as well as their economic performance has changed over time.

The second level-analysis, on the other hand, uses ratios to investigate the respective effects the different knowledge acquisition strategies have had for the various firms' measures of innovation. As such, the second-level analysis provides a first insight into how important the different knowledge acquisition strategies have been for the selected firms' innovative success over time.

It is important to note that due to the fact that all the selected firms are a result of mergers, the analysis treats the selected firms as 'supra firms', i.e. the analysis presents the firms as if they have always consisted of their current merged structure. As such, the analysis collects data on all the firms' ancestor companies. There are two advantages of collecting data on all the ancestor firms and treating the selected firms as 'supra firms': i) it allows the research to build time into its analysis, which is a crucial aspect of the research question and ii) it allows a more representative picture of the firms in their current configuration. The latter point needs deeper clarification; as the selected firms have undergone mergers, they now represent large groups with many subsidiaries. In all the three cases, many subsidiaries' names refer to their previous parent companies' names, e.g. Astra Pharma AB, Astra Biotech AB and Zeneca Pharmaceuticals Ltd. In some cases, the subsidiaries use their own names, for example, on their own publications and patents. Hence, collecting data on the various ancestor firms provides a more representative picture

of some of the measures used than would result if data were collected only on the formal pharma groups' names.

Only one firm in the sample, Pfizer, has kept its own name over time, allowing the research to analyse the real Pfizer history as well as its 'supra firm'.

The next sections will be analysing each firm in turn (Pfizer, AstraZeneca and GSK) according to a consistent framework: analysis 1 (strategy, innovation) analysis 2 (evaluation of the strategies).

4.2.1 Pfizer

Pfizer was founded in 1849 by cousins Charles Pfizer and Charles Erhart in Brooklyn (New York). A milestone of Pfizer's early evolution was its pioneering mass production of citric acid from sugar. In the second half of the last century, Pfizer's history was characterised by intense pharmaceutical research and constant expansion. In the new millennium, as a result of three extensive mergers (Warner-Lambert Co in 2000, Pharmacia in 2003 and Wyeth in 2009) Pfizer is one of the largest pharmaceutical companies in the global arena. (Appendix A gives more complete information about the different mergers).

Analysis 1: Reliance on knowledge acquisition strategies, innovative success and economic performance

As mentioned above, analysis one uses document- and database-analyses to create a quantitative picture of Pfizer's reliance on the different knowledge acquisition strategies, its innovation and its economic performance over time.

Firm strategies

- In-house R&D

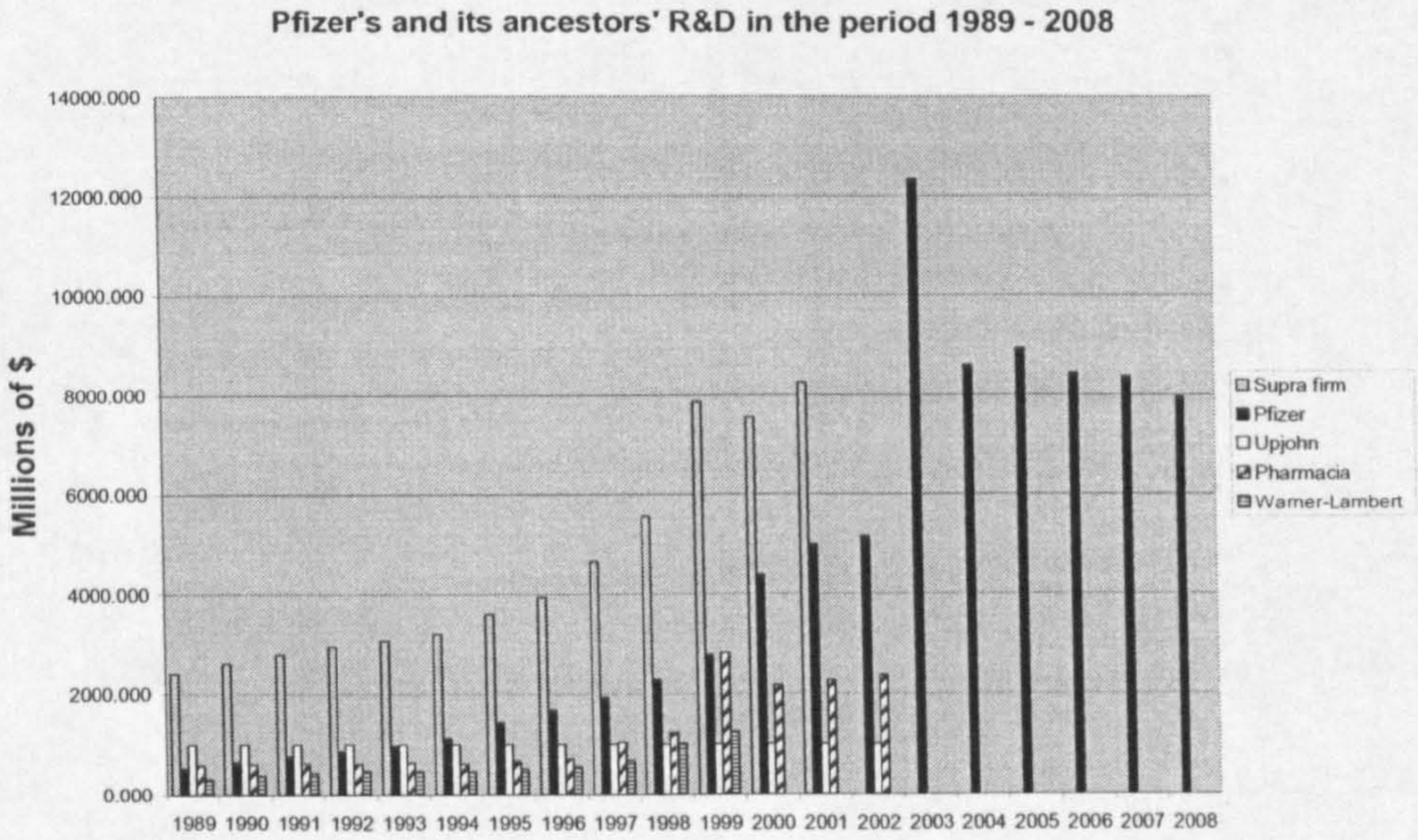
As seen in the methodology chapter, R&D expenditure and R&D intensity are the most commonly used measures for absorptive capacity. The latter was introduced by Cohen and Levinthal (1989).

There are two aims related to the investigation of Pfizer's R&D:

The first aim is to obtain data on Pfizer's and its ancestor firms' R&D expenditure, as this will provide an indication of Pfizer's reliance on R&D. Data on Pfizer's and its ancestor firms' R&D expenditure was collected for the period 1989-2008, with the data on R&D expenditure for Pfizer taken from its 10-K forms (obtained from the Security Exchange Commission – SEC) and the R&D expenditure of its ancestor firms, Warner-Lambert and Pharmacia, obtained from Bloomberg. The R&D expenditure for Pfizer and its ancestor firms are presented in Figure 4.1. Presenting the data on all the firms separately before the mergers between Pfizer and Warner-Lambert in 2000 and between Pfizer and Pharmacia in 2003 allows the analysis to view Pfizer's actual reliance on R&D as well as treating Pfizer as a supra firm.

The chart in Figure 4.1 shows that Pfizer has multiplied its R&D fifteen times as the Pfizer group, and almost three and half times as the Pfizer supra firm, in the last twenty years. Between 1989 and the second half of the nineties, Pfizer's R&D was relatively stable. In the second half of the nineties, R&D started to grow much more significantly, until 2003 when it peaked, in coincidence with the major merger of Pfizer with Pharmacia and Upjohn, before settling midway between the level reached before the acquisition and the peak. Figure 4.1's values are nominal.

Figure 4.1

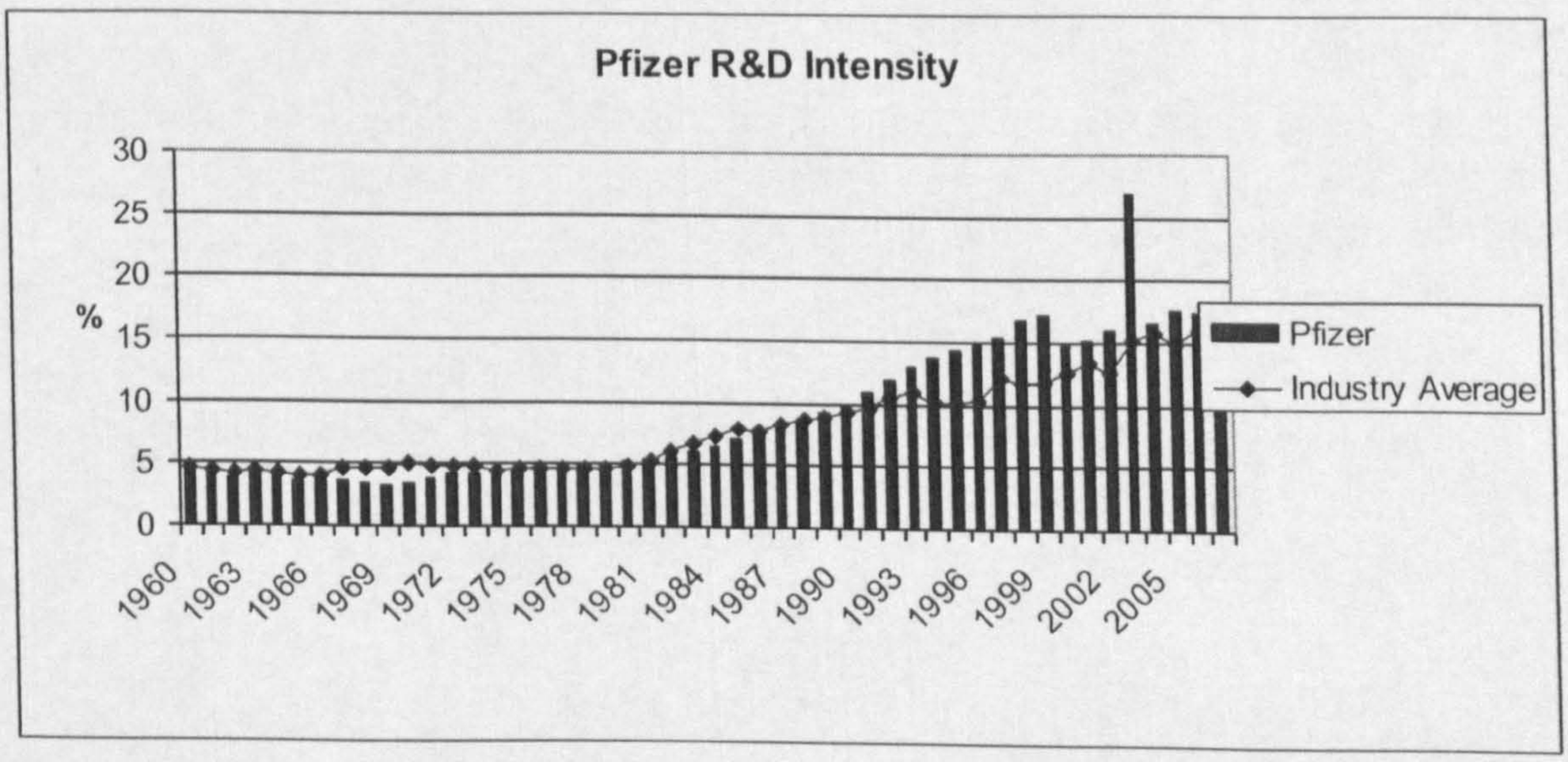


(Source: Pfizer's 10-K reports and Bloomberg)

The second aim is to compare Pfizer's intensity, i.e. the percentage of revenue spent on R&D, with the industry average. Firm level data was collected from the S&P database, which consists of 323 firms and covers the period 1950-2007.

The chart in Figure 4.2 shows that ever since the early nineties, Pfizer has spent a higher proportion of its revenues on R&D than the industry average, with a significant peak in 2004. Before this period, Pfizer's R&D intensity was in line with the industry average.

Figure 4.2



(S&P database)

- Number of collaborations

As seen in the methodology chapter, the investigation of the reliance on collaborations focused primarily on the number of collaborations that the selected firms have engaged in over time.

A first indication of the number of collaborations was found in Richardson and Evangelista (2002), holding that "Pfizer began focusing on alliances in the 1980s much earlier than many of its competitors and, today, it collaborates in some form with 450 companies; 250 in R&D alone. Other collaborations involve sales and marketing, building on Pfizer's reputation".

Given the high number of collaborations, it is intriguing to note that collaboration has been one of Pfizer's major strategies for acquiring knowledge in biotechnology. In particular, Atun *et al.* (2007) show that since the mid 1990s, Pfizer has enhanced its genomics drug discovery by collaborating with third party technology providers, and by 2000 they had formed a "six pack alliance" (p.333) with the following partners: ArQule, Aurora Biosciences Corp, Celera Genomics group, Evotec BioSystems AG, Incyte Genomics Inc and Neurogen Corp, whereby each partner brought expertise in early stage genetics and high-throughput screening. According to Atun *et al.* (2007), this partnership strategy marked a significant shift for Pfizer in its approach to drug discovery, acknowledging the advantages of bringing ideas in from outside.

Having obtained a first insight into the scale and importance of collaborations, the research designed two distinctive methods for investigating the reliance on collaborations.

The first method used to investigate Pfizer's reliance on collaborations sought to identify the 'real' number of collaborations initiated and carried out over the years. In order to provide a further understanding of the relative importance of this strategy, financial data associated with the collaborations were obtained from annual reports. Interestingly, information about the costs of R&D related to collaboration appears in Pfizer's annual reports only between 2005 (data referring to 2004) and 2009 (data referring to 2008), due perhaps to a change in the interpretation of the adopted US Financial Reporting Standards and, presumably, the materiality of the amounts. R&D related to collaboration refers to the amount of R&D expenses incurred by Pfizer in a given year and which was associated with collaborative projects in that year. For example in 2007 Pfizer "entered into a license and collaboration agreement with Adolor Corporation (Adolor) to develop and commercialize ADL5859 and ADL577, proprietary delta opioid receptor agonist compounds for the treatment of pain. In 2007, [Pfizer] expensed a payment of $32 million, which was included in Research and Development expenses." (Pfizer, 2007, Annual Report, p.8).

The result of this investigation is presented in Table 4.1, and shows that Pfizer has over the last six years initiated seventeen new collaborations at a variable pace of between one and four per year; with the company reporting almost one billion dollars in the same period for R&D related to collaborations. Comparing this result with the figures provided by Richardson and Evangelista (2002), the number seems very low, though this could simply mean that Pfizer only included collaborations with significant costs attached to them in its annual report.

Table 4.1 shows that over the years 2004-2009, Pfizer has initiated a steady number of new collaborations every year. This is confirmed by the constant increase of yearly expenditure in R&D related to collaborations, both in terms of absolute amounts and as a percentage of total R&D.

Table 4.1: R&D expenditure related to collaborations in the period 2004-2009 – Pfizer*

	2004	2005	2006	2007	2008	2009
R&D related to collaborations (in $m)	18	140	153	312	300	n/a
R&D related to collaborations (% of total R&D)	0.21%	1.57%	1.81%	3.73%	3.50%	n/a
Number of new collaborations	1	3	4	4	3	2

(Source: Pfizer's annual reports)

* NB: in addition there were two major mergers in 2000 and 2003.

Another attempt to obtain a picture of the different types of collaborations that the selected firms have engaged in, and how this reliance had changed over time, was done by collecting publication data from ISI Web of Knowledge for the period 1980-2008. As mentioned in the methodology section, as co-publications result from the scientists' own decisions to publish together, they can be seen as informal collaborations.

The investigation into the selected firms' publications followed a three-step analysis, whereby the first step sought to identify the total number of publications over time, whilst the second and third steps sought to include two major groups of co-authors, i.e. universities and big pharmaceutical companies.

The first step was carried out simply adding the name "Pfizer" to the address line and searching for the number of publications Pfizer has been involved in publishing for each of the year in the period 1980-2008.

In the second step, the term "univ" was matched in the address line of all Pfizer's co-authors in the database, in order to identify how many publications were co-authored each year by Pfizer and anyone affiliated with a university.

The third step swapped the word "univ" with the names of the 15 largest (by revenue) pharmaceutical companies in the corresponding year for the entire period 1980-2008, in order to identify how many publications were co-authored each year by Pfizer and anyone affiliated with one or more of the currently largest pharmaceutical companies. The identification of the top 15 pharma companies for each of the years in the period 1980-2003 was based on the S&P revenue data, whilst in the period 2003-2008 it relied on independent pharmaceutical company ranking, e.g. contract pharma (Contractpharma, 2007). Table 4.2 provides the names of the firms that have ranked at least once among the 15 largest firms in any year in the period 1980-2008.

Table 4.2: Top pharma firms in period 1980 - 2008

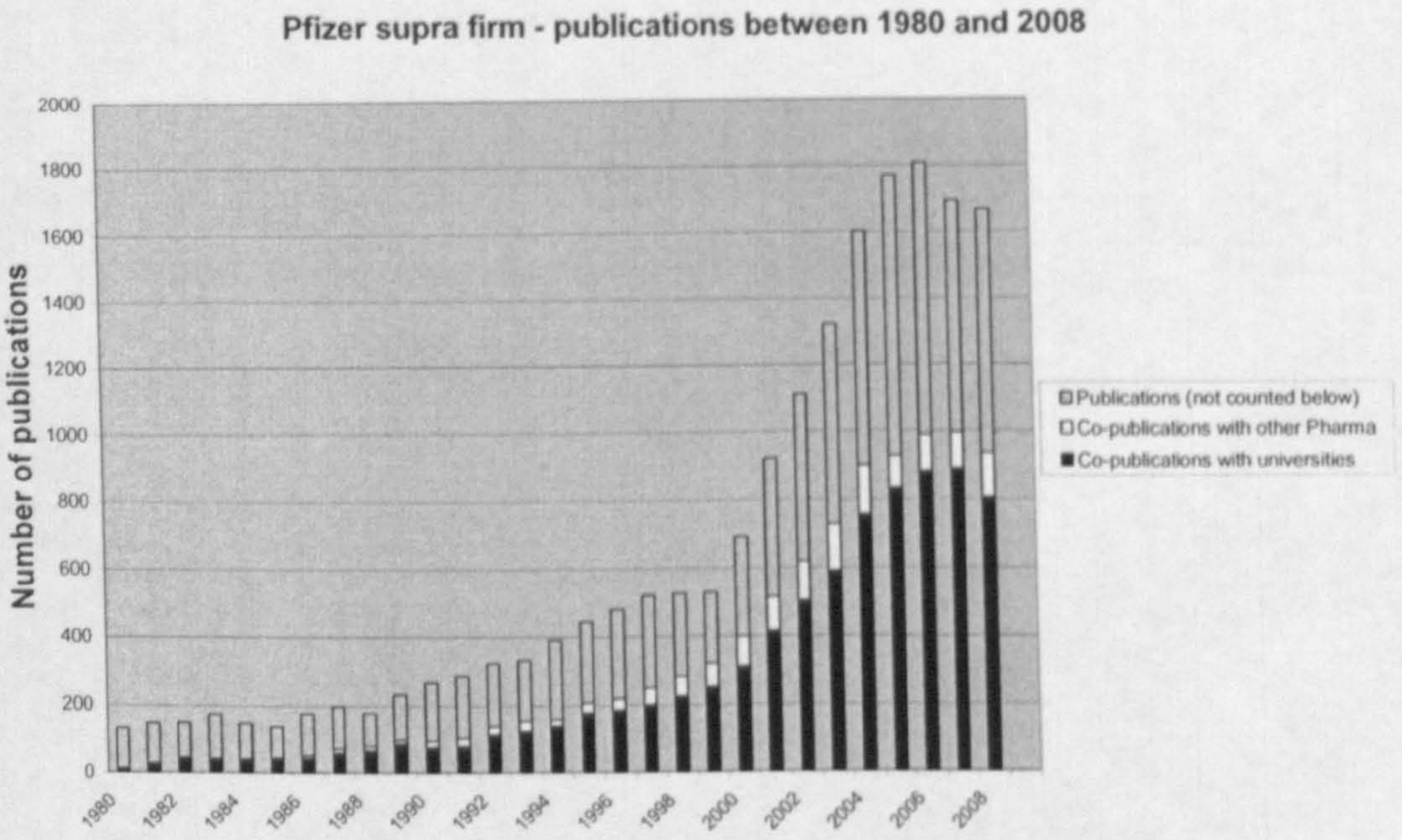
Abbott Laboratories	Novartis AG - Spon ADR
American Cyanamid Co	Pfizer
Amgen	Pharmacia Corp
Astrazeneca	Rhone-Poulenc Rorer
Aventis	Roche Holdings Ltd -ADR
Biogen	Sanofi-Synthelabo -ADR
Bristol Myers Squibb	Schering-Plough
Eli Lilly	Smithkline Beckman Corp
Genentech	Smithkline Beecham Plc – ADR
Glaxosmithkline	Squibb Corp
Hoechst AG – ADR	Sterling Drug Inc
Johnson & Johnson	Warner-Lambert Co
Lilly (Eli) & Co	Wyeth
Merck	

The results of the investigation are illustrated in the chart in Figure 4.3 and refer both to Pfizer's own collaborations as well as the collaborations of Pfizer's supra firm. It is worth noting that due to the research efforts behind the papers and the time it takes to publish, the number of the co-publications must be seen as a result of collaborations taking place 4-6 years before the published data (Nightingale and Martin, 2004).

Figure 4.3 shows that since the 1980s the number of the Pfizer supra firm's publications has increased more than thirteen times, to reach its peak in 2006. In the meantime, the co-

publications with universities have increased more than proportionally, from less than 20% of all publications in the early eighties to around 50% in the most recent years. On the other hand, collaboration with other big Pharma has produced a proportional number of co-publications, which kept them at around 5% of all publications, until the mid-nineties, when they reached 10% of the total, to go back to a lower percentage in the latest years. The high number of co-publications provides a better understanding of the number of collaborations found in Richardson and Evangelista (2002).

Figure 4.3



(Source: ISI Knowledge database)

As a final remark, due to the extensive numbers of small and medium pharmaceutical and biotechnology companies, it was not possible to obtain a representative picture of their involvement in Pfizer's publications and to distinguish the co-publications with them from the publications solely authored by Pfizer.

- Acquisitions

In terms of acquisitions, Pfizer's annual reports state that Pfizer has carried out sixteen further acquisitions of various sizes, since its major merger with Pharmacia, at a variable pace of between one and three a year, for a total value of over eight billion dollars (Table 4.3).

Table 4.3 shows that over the years 2004-2009, Pfizer has completed a steady number of acquisitions every year. This, however, has been accompanied in lower yearly expenditure in R&D related to acquisitions, both in terms of absolute amounts and as a percentage of the total R&D.

Table 4.3: R&D expenditure related to acquisitions in the period 2004-2008 – Pfizer*

	2004	2005	2006	2007	2008
R&D related to acquisitions (in $m)	1,071	1,662	953	283	610
R&D related to acquisitions (% of total R&D)	12.48%	18.66%	11.30%	3.38%	7.11%
Number of completed acquisitions	3	2	2	2	6
Value of completed acquisitions (in $m)	2,263	2,104	2,320	464	1,184

(Source: Pfizer's annual reports)

* NB: in addition there were two major mergers in 2000 and 2003

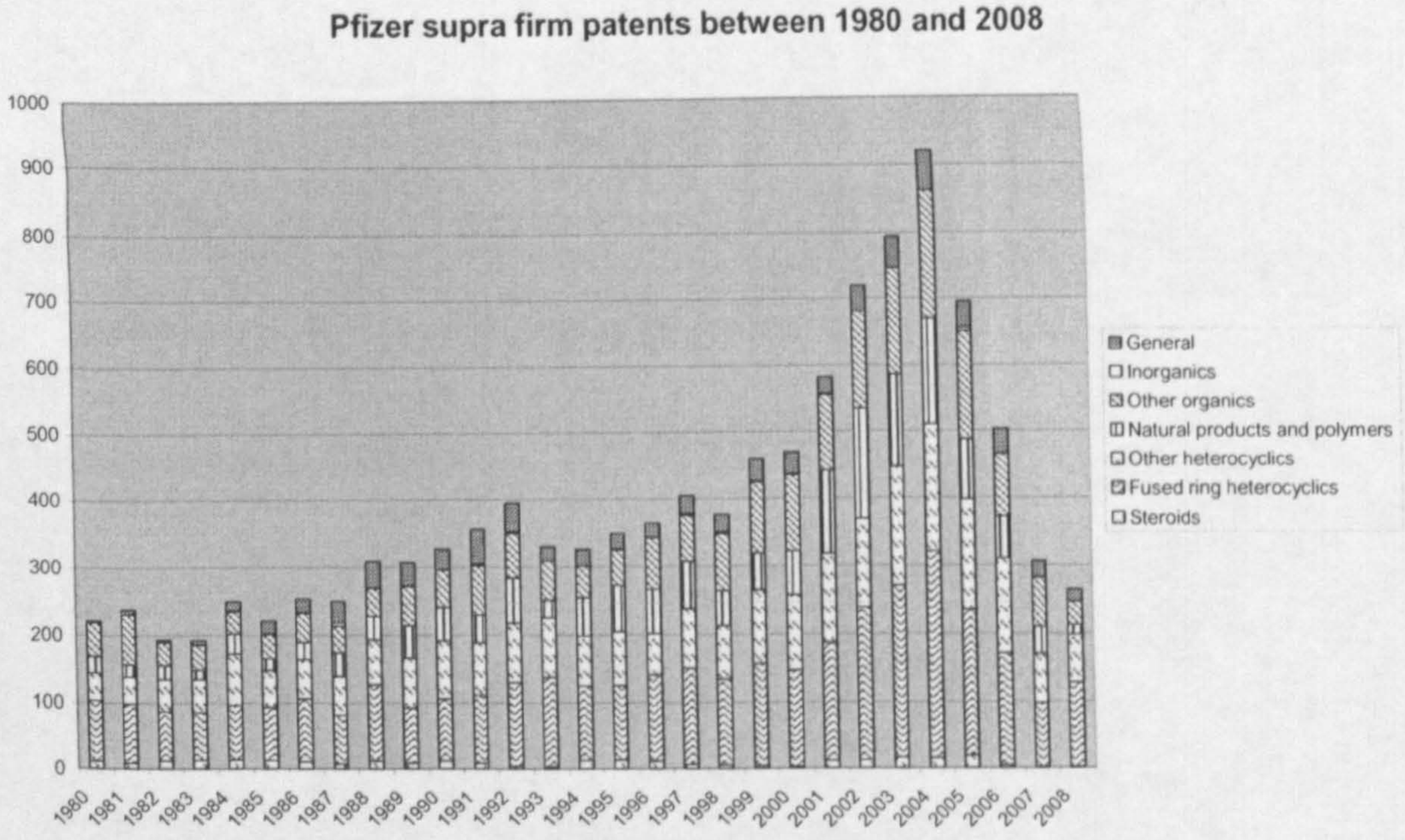
Innovation

- Patents

As indicated in the methodology section, patents can be used as a proxy for a firm's potential for innovation. Patent data were collected from the Derwent database for the period 1980-2007 both for Pfizer and Pfizer's supra firm and presented in Figure 4.4.

The chart in Figure 4.4 shows that the Pfizer supra firm has produced a slightly increasing number of patents between the early eighties and the beginning of the new millennium. On the other hand, in the first four years of the new millennium, coinciding with two major mergers, the number of patents increased dramatically, peaking in 2004, coupled with a similar drop in the latest years. All along, the patents in their respective groups have grown proportionally, keeping the same mix.

Figure 4.4



(Source: Derwent)

- Number of drugs

Though the number of patents gives insight into Pfizer's R&D activity and can be seen as an indication of the potential for innovations, the number of drugs is more revealing of the actual innovations carried out by pharmaceutical firms. Building on this, the research sought to trace the origin of the drugs in the portfolio and calculate the contribution of the drugs stemming from each of the different firm strategies, in-house R&D, collaborations

and M&As, as this would show the actual contribution of the products stemming from the different firm strategies. An explanation of the method is given below.

The investigation into the effects of the different strategies was initially hampered by a lack of available data on the number of drugs Pfizer has launched over time. This made it difficult to trace the origins of the products, i.e. to the extent they derived from in-house R&D, collaborations and M&As, which was the information that would enable comparisons between the different strategies over time.

Despite this initial limitation, a valuable source of information was found in a section of Pfizer's annual report called: "Revenues – major pharmaceutical products". Using this section as a starting point it was possible to identify Pfizer's key drugs as well as the revenues obtained from them. From this, an investigation followed, using Pfizer's own webpage, the FDA's webpage and Thomson Pharma database, into the origins of the products, to the extent that they were a result of in-house R&D, collaborations or M&As. By allocating all the drugs to either category, it was then possible to understand the number of drugs stemming from each strategy, as well as the revenues attached to them, as illustrated in the Table 4.4 below.

The main limitation associated with this method is that it is only possible to allocate the key products, rather than including the whole portfolio of drugs. However, cross-checking the number of drugs allocated to in-house R&D with data presented in an article in the New York Times (18th July, 2006 by Berenson), stating that Pfizer only created 'a handful of drugs' in the period 2000-2005, indicates that the number achieved in the analysis for in-house drugs was reliable and includes the following drugs: Geodon (2001), Vfend (2002), Relpax (2003), Caduet (2004), whereby the latter was reported to be a combination of two of Pfizer's 'blockbuster' drugs. According to Pfizer's own website, it further

launched Sutent (2006) and Champix (2006). As such, only drugs innovated via in-house R&D could be indicated with certainty.

Another limitation refers to the fact that although extensive information covering the most recent years is available for public sources, making it possible to trace the origins of the most recent drugs, this proved harder for 'older' drugs, e.g. Cardura. The implication of this is that the available data did not allow any investigation prior to the merger in 2000. The rationale for choosing information referring to 2007 was to get the most up to date and complete figures, and at the same time the products from both the mergers would still be included in its portfolio.

Although an indication of the number of key drugs stemming from either strategy is interesting, the overall revenue stemming from each strategy probably provides a better measure of each strategy's importance.

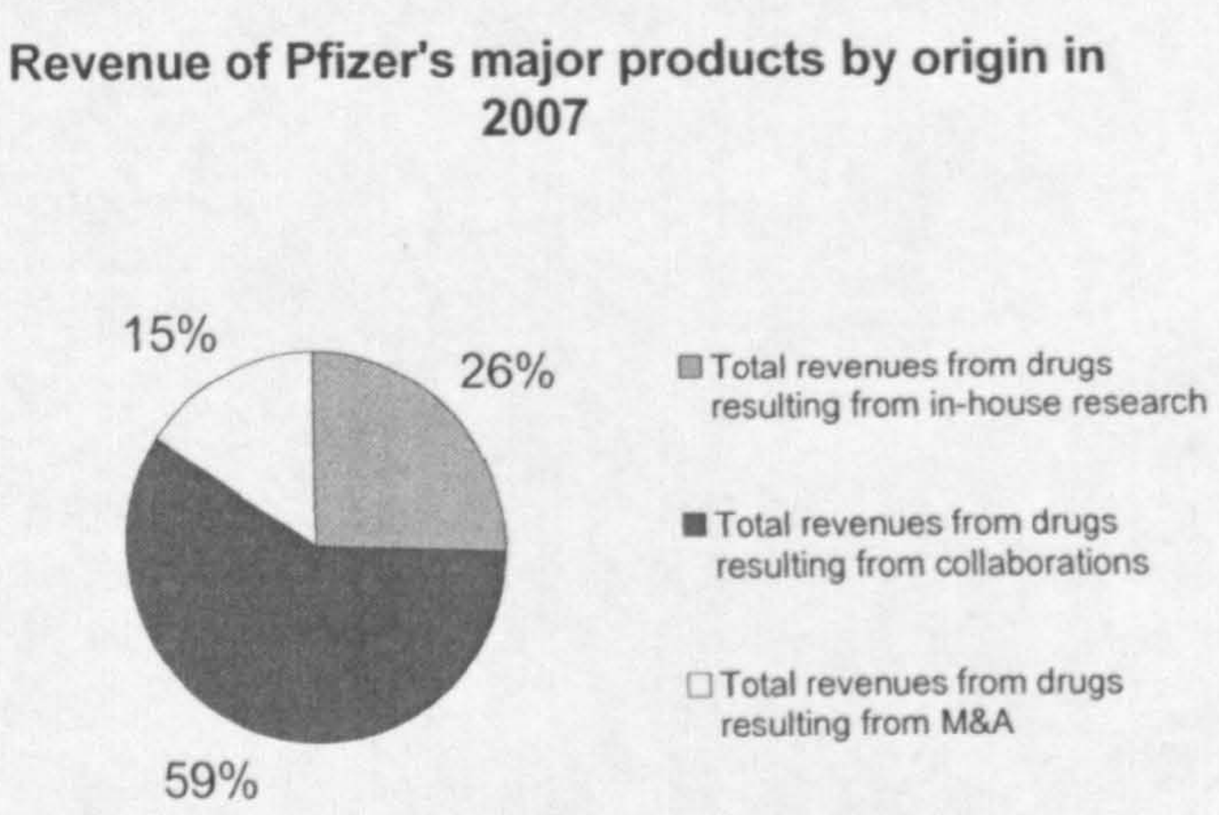
Table 4.4 and Figure 4.5 clearly illustrate the importance of collaborations, with their contribution counting twice as much as the other two strategies in terms of total revenue generated. These data, though, must be seen in relation to the sole contribution of Lipitor, which according to Pfizer's online corporate communications resulted from a co-promotion agreement with Warner-Lambert before the merger and is the world's most profitable drug. By removing Lipitor from the sample, the importance of the different strategies would be as follows: in-house R&D 39%, collaborations 38% and M&As 23%, i.e. they would be weighted more equally.

Table 4.4: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – Pfizer

	Revenues from each drug ($ millions)	
Drugs resulting from in-house research		
Diflucan (1990 – Pfizer)	415	
Zoloft (1992 – Pfizer)	531	
Norvasc (1992 – Pfizer)	3,001	
Viagra (1998 – Pfizer)	1,764	
Geodon (2001 – Pfizer)	854	
Vfend (2002 – Pfizer)	632	
Relpax (2003 – Pfizer)	315	
Caduet (2004 – Pfizer)	568	
Sutent (2006 – Sugen which merged into Pfizer)	581	
Champix (2006 – Pfizer)	883	
Total revenue from these drugs ($ millions)		9,544
Drugs resulting from collaborations		
Lipitor (Warner-Lambert)	12,675	
Lyrica (Warner-Lambert)	1,829	
Celebrex (Searle)	2,290	
Aricept (Eisai)	401	
Camptosar (Yakut Honsha, i.e. Sanofi Aventis)	969	
Zithromax (Pliva)	438	
Zyrtec (UCB pharma)	1,541	
Co-promotion (alliances)	1,789	
Total revenue from these drugs ($ millions)		21,932
Number of drugs resulting from M&As		
Neurotin (Parke-davis)	431	
Xanax (Pharmacia, i.e. Pfizer Upjohn)	325	
Zyvox (Pharmacia)	944	
Detrol (Pharmacia and Upjohn)	1,190	
Aromasin (Pharmacia and Upjohn)	401	
Xalatan (Pharmacia and Upjohn)	1,604	
Genotropin (Pharmacia and Upjohn)	843	
Total revenue from these drugs ($ millions)		5,738

(Source: Pfizer's 2009 annual report and Thomson-Pharma, database)

Figure 4.5



(Source: Pfizer's 2009 annual report)

- Economic performance

The economic performance was measured using: i) firm growth and ii) market value.

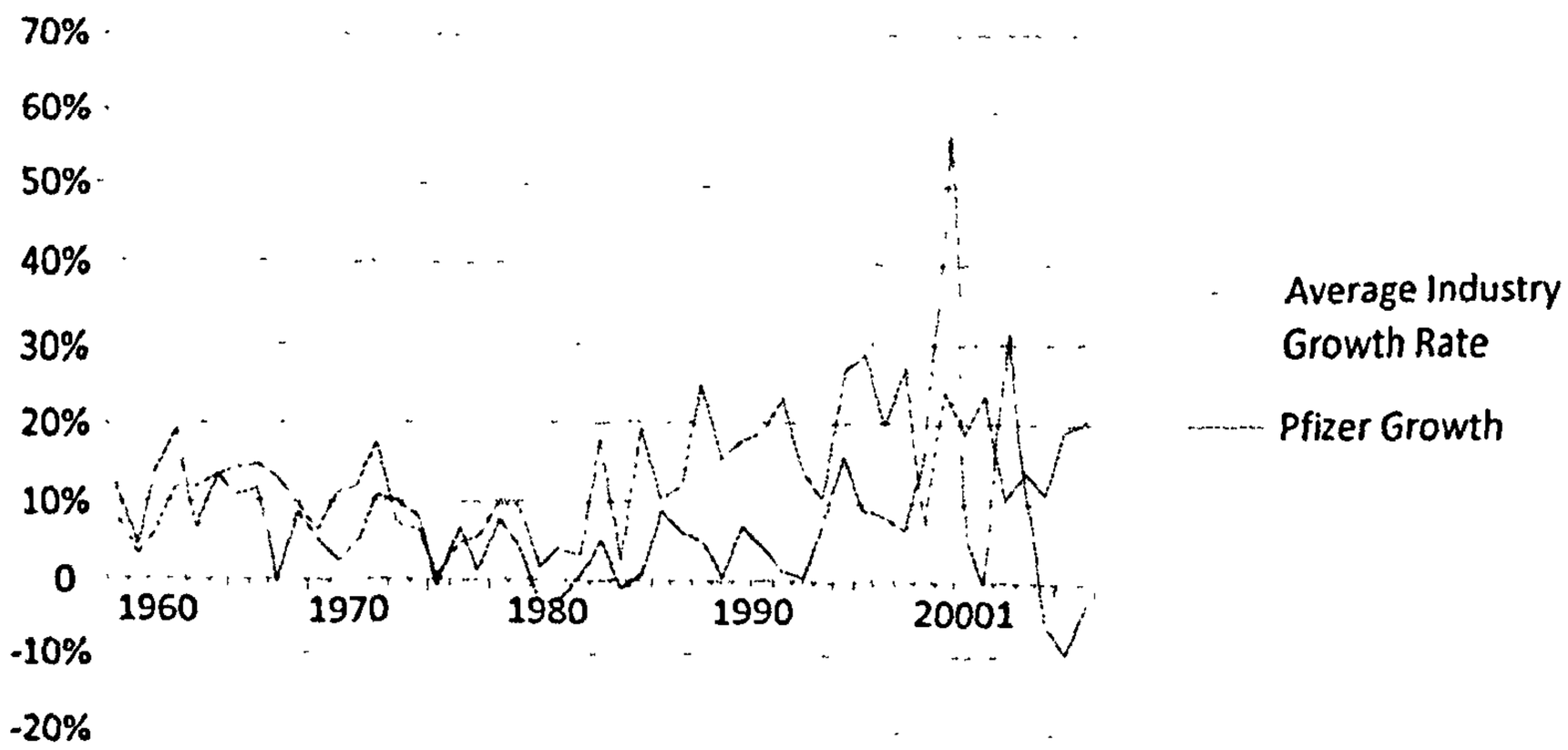
- Growth

Growth rate is defined as log(sales)t-log(sales)t-1. The revenue data was collected from the S&P database for the period 1959-2007.

Pfizer's growth shows a continuous, almost uninterrupted, positive trend for the period 1959-2007 (Figure 4.6), with two peaks in the years of the mergers with Warner-Lambert and Pharmacia, in 2000 and 2003 respectively. It is interesting to note, however, that immediately after each of the mergers, Pfizer's growth has slowed down, reaching new lows each time (in 2005 this is in fact a negative growth). It is fair to note, though, that given that the annual growth is calculated as a percentage of the previous year's turnover, the 2004 12% growth rate represents an increase in turnover whose actual magnitude is much higher than that represented by the 1995 16% growth rate. The reason for this lies on the higher scale reached by the turnover after each increase and, in particular, after the 2001 and 2003 peaks.

However, the observed pattern objectively suggests that the combined drug portfolios obtained through the mergers were not effective enough in sustaining the company's previous growth trend.

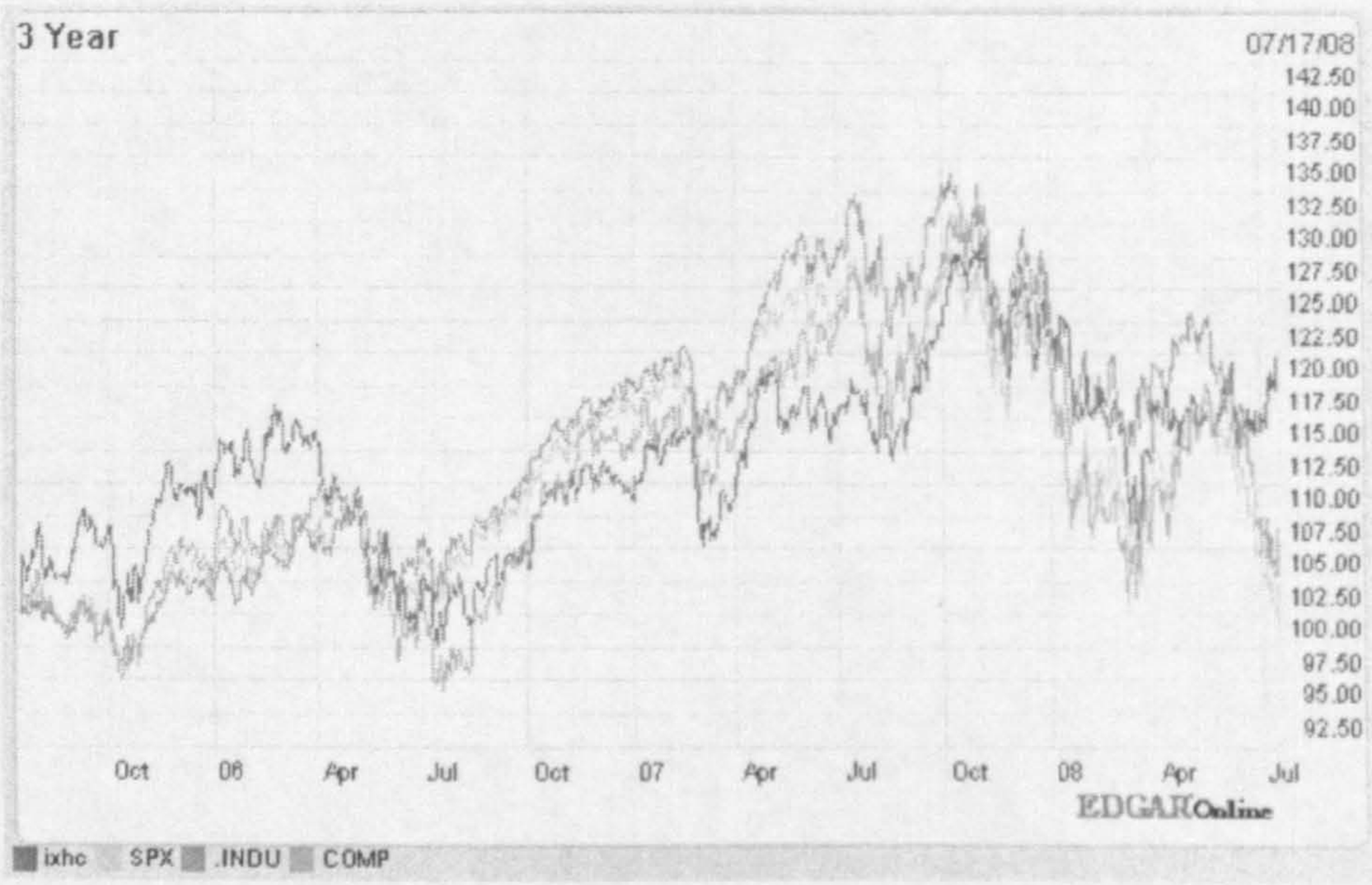
Figure 4.6



- Market value

Pfizer's market value over the last ten years has been analysed in comparison with the S&P 500 index of the NASDAQ. The rationale for the choice of this index is twofold: the sector index closest to Pfizer and available for analysis is the Health Care Index (ixhc) of which the S&P 500 is a good proxy (Figure 4.7) and the four companies belong to the S&P 500.

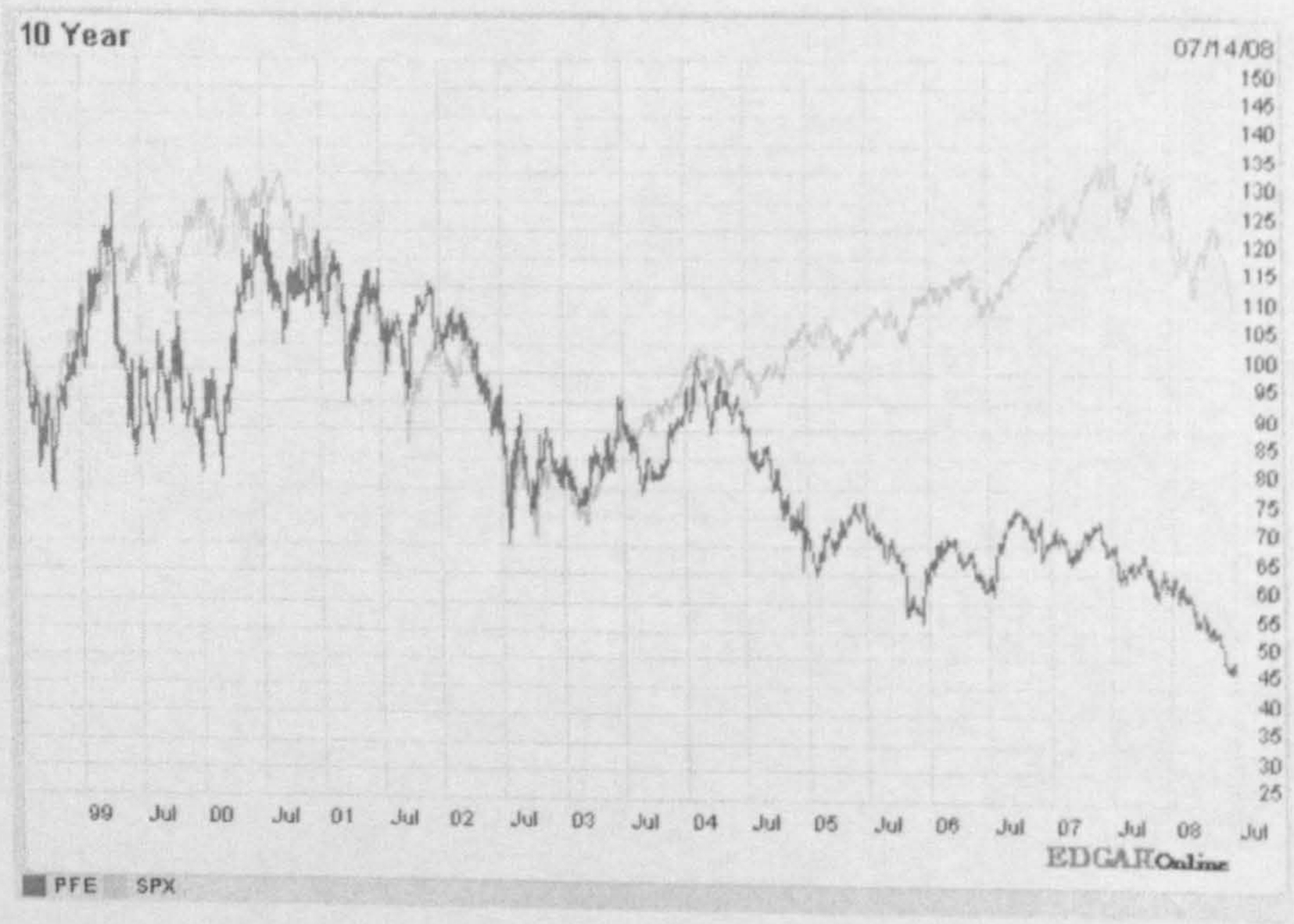
Figure 4.7: Health Care Index (ixhc) and S&P index (SPX) compared



(Source: Nasdaq)

From the comparison of Pfizer's market performance with the S&P 500 index (Figure 4.8), it appears that Pfizer's performance has almost overlapped the market performance between 1999 and the end of 2003. From 2004, Pfizer's market performance has been declining whilst the market kept growing. This seems to suggest that the 2003 takeover has not been accepted with great enthusiasm by the market.

Figure 4.8: Pfizer's market value 1998-2008



(Source: Nasdaq)

Analysis 2: The importance of the different knowledge acquisition strategies for Pfizer's innovative success

As seen above, analysis two uses the various data in the first-level analysis to evaluate the distinctive effects the different knowledge acquisition strategies have had on the various firms' measures of innovation. In order to provide as realistic an account as possible, the analysis takes account of time lags, i.e.: publications 4-6 years, patents 6-8 years and drugs 8-12 years after inception (Nightingale and Martin, 2004).

By analysing the data on R&D (Figures 4.1 and 4.2), publications (Figure 4.3), patents (Figure 4.4) and origins of drugs (Table 4.4), it appears that in coincidence with Pharma entering into biotechnology (early-nineties, see chapter one), R&D expenditures and collaborations increase significantly. Approximately six to eight years after, the number of patents rises sharply. However, this resulted in just one new in-house originated drug a year in Pfizer's portfolio between 2001 and 2007.

The document analysis showed that the key strategy for entering into biotechnology was establishing collaborations, e.g. the 'six pack alliance' in genomics. However, although Atun *et al.* (2007) claim that this has had an impact on drug discovery, acknowledging the advantages of bringing ideas in from outside, none of Pfizer's current portfolio of drugs stemming from collaborations (Table 4.4) can be ascribed to the 'six pack alliance'. Instead, they all result from pure in-licensing agreements and they account for more than twice the revenues of drugs originated by in-house R&D.

Hence, from the above evaluation of Pfizer's innovation, collaborations do appear to have created significant value, but little evidence is found that collaborations have enabled the firm to *create* innovation or to build new capabilities.

In terms of the mega-merger strategy that Pfizer has undertaken in the new millennium, due to the fact that it takes approximately 11 years to develop drugs, it is too early to provide any clear picture of their effects on Pfizer's innovative performance. However, comparing the R&D expenditure (Figure 4.1), number of publications (Figure 4.3) and number of patents (Figure 4.4) after the merger, it is interesting to note that the peak of R&D expenditure coincides with Pfizer's 2003 merger, whilst both publications and patents peak one or two years after. However, although the number of publications remains high, the number of patents goes down sharply immediately after, reaching the level of the early eighties. Also, allowing a time lag of six years between the R&D expenditure and number of patents, the R&D cost per patent is approximately three times higher after the merger than before, bearing in mind that by no means all patents become innovations.

4.2.2 AstraZeneca

AstraZeneca (AZ) is a result of the 1999 Astra AB and Zeneca Group Plc merger. Respectively Astra dates back to 1913, as a fully integrated pharmaceutical company, and Zeneca emerged as a spin-off from Imperial Chemical Industries in 1993, as an international wide spectrum bioscience group. Appendix A gives more complete information about the different mergers.

Analysis 1: Reliance on knowledge acquisition strategies, innovative success and economic performance

As mentioned above, analysis one uses document and database analyses to create a quantitative picture of AstraZeneca's reliance on different knowledge acquisition strategies, its innovation and its economic performance over time.

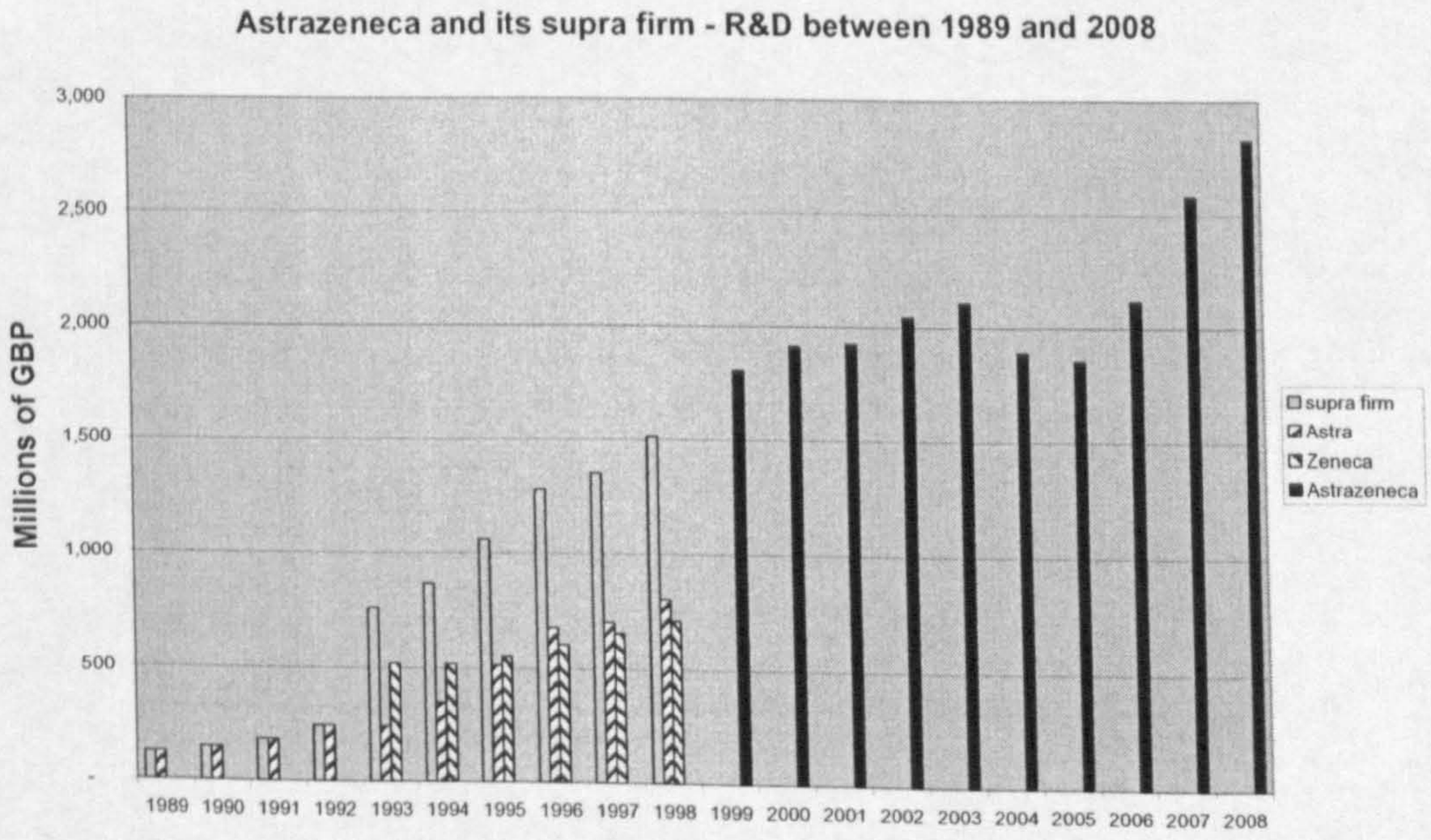
Firm strategies

- In-house R&D

As with Pfizer, data on AstraZeneca's R&D expenditure was obtained from 10-K forms (accessed through AstraZeneca's own website) and data on its ancestor firms' R&D expenditures (i.e. for Astra AB and Zeneca Plc) were collected from Bloomberg for the period 1989-2008. However, the fact that AstraZeneca is a result of the merger between Astra and Zeneca in 1999 has some implications for understanding how its reliance on R&D has changed over time. Only by treating AstraZeneca as a supra firm in the years before the merger is it possible to provide an understanding of its reliance on R&D over time.

The chart in Figure 4.9 shows that AstraZeneca has multiplied its R&D more than ten times, as a supra firm, in the last twenty years. The increase has been steady (almost on a straight line) from the early nineties to the fourth year into the merger and has started again in the last three years. Figure 4.9's values are nominal.

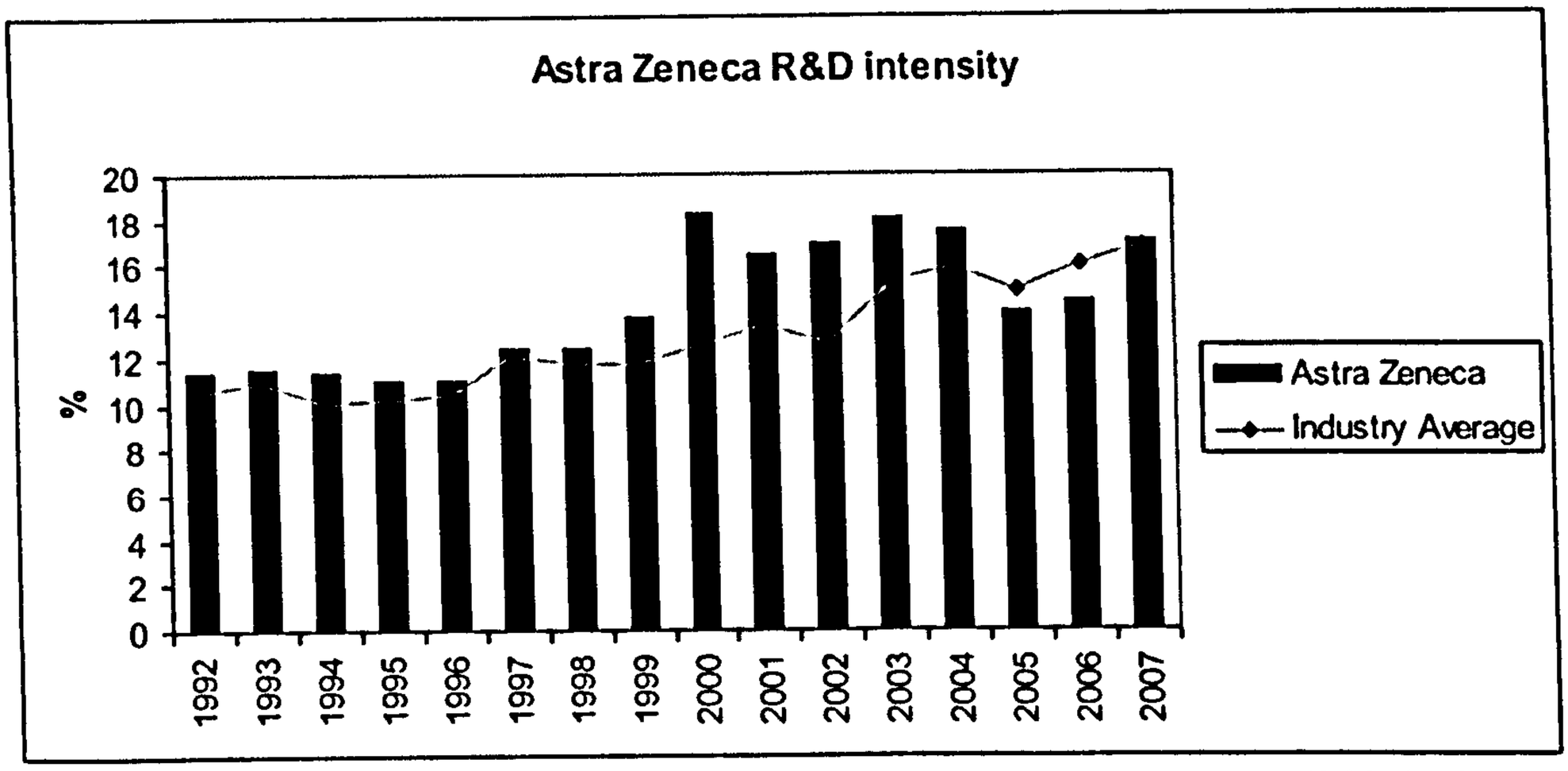
Figure 4.9



(Sources: AstraZeneca's 10-K reports and Bloomberg)

It is only between 1999 and 2004 that AstraZeneca has had an above the industry average R&D intensity, as shown in the chart of Figure 4.10. In 2005 and 2006, Astra Zeneca's R&D intensity has even been below the industry average.

Figure 4.10



(S&P database)

- Number of collaborations

In the case of AstraZeneca, the groups 'actual' number of collaborations was obtained from its annual reports for the entire post-merger period 1999-2007. However, as opposed to Pfizer, AstraZeneca does not provide the R&D expenditure related respectively to collaborations and to acquisitions.

The results of the investigation are reported in Table 4.5, showing that the number of new collaborations has increased significantly in the most recent years, with their average number per year more than doubling in 2005 and almost doubling again in 2006. Detailed information regarding the types of collaborations that AstraZeneca has entered into since their merger can be found below in Table 4.6.

Table 4.5: R&D expenditure related to collaborations in the period 2001-2009 – AstraZeneca

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of new collaborations	2	1	2	1	5	9	9	Requested info	9

(Source: AstraZeneca's annual reports)

Zeneca entered into collaborations with Incyte Pharmaceuticals in order to acquire knowledge in genomics in the mid-nineties. Table 4.6 summarises the nature of the collaborations after the 1999 merger.

Table 4.6: AstraZeneca's collaboration history

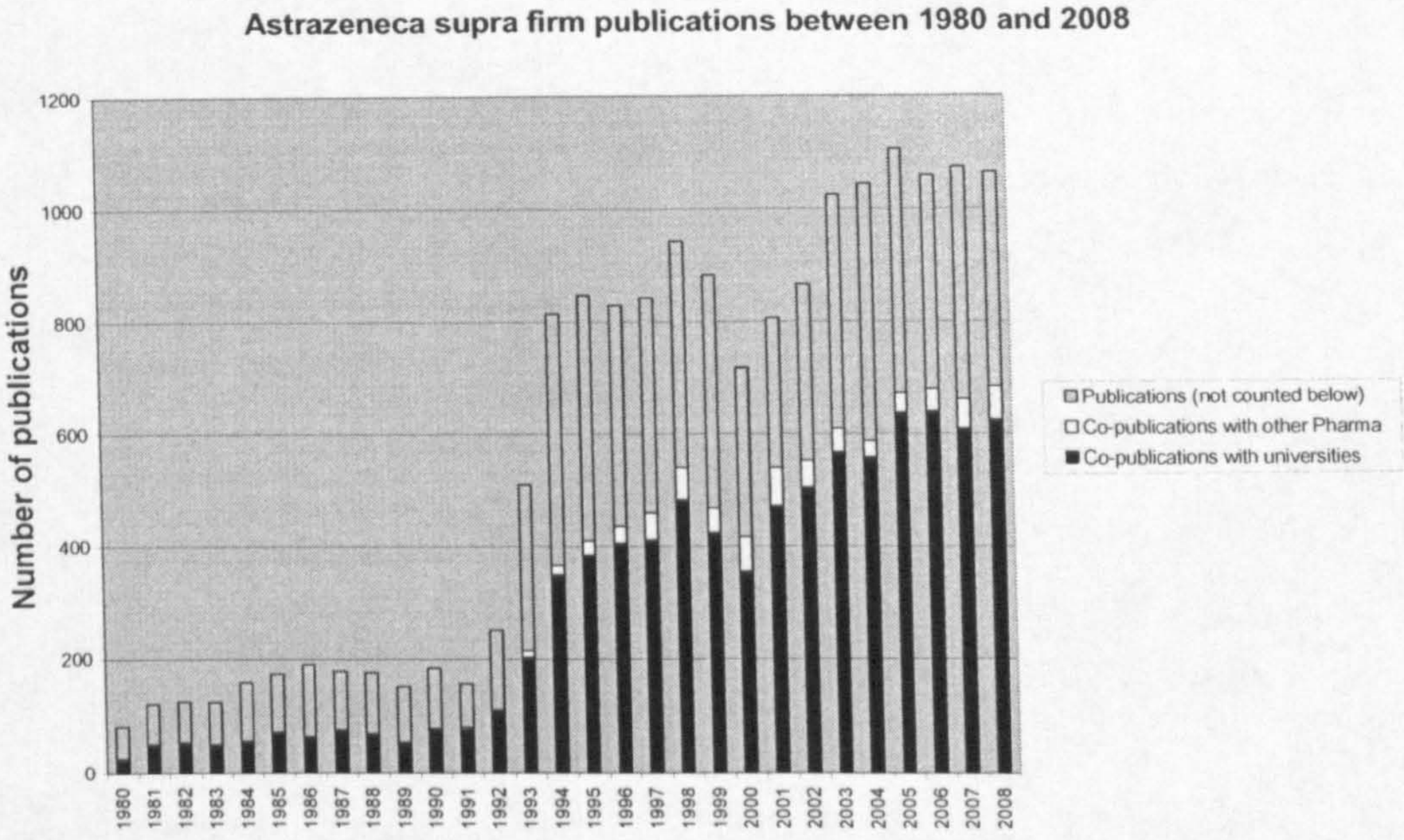
Year	Company	Specifics
2007	Bristol-Meyers Squibb	Develop and commercialise two investigational being studied for the treatment of Type 2 Diabetes (both compounds were discovered by BMS).
2007	Argenta Discovery Limited	Aimed at identifying improved bronchodilators to treat COPD (teams from both companies).
2007	Palatin Technologies, Inc	Global licensing and research collaboration. The collaboration is aimed at discovering, developing and commercialising small molecule compounds that target melancortin receptors and have potential in treating obesity, diabetes and metabolic syndrome.
2007	University of Texas Southwestern Medical Centre at Dallas, US	To accelerate scientific discovery and therapeutic advancement for depression.
2007	University of Texas M. D. Anderson Cancer Centre	Partnership to develop platforms and clinical targets for new drugs in chronic pain.
2007	Karolinska Institute, Sweden	To expand research capabilities in positron emission tomography, providing early signalling of potential efficacy for our Alzheimer's products.
2007	Banner's Alzheimer Institute, Phoenix	Alzheimer alliance.
2007	Washington University	Alzheimer alliance.
2007	Silence Therapeutics plc	R&D collaboration is intended to discover and develop proprietary si\rna molecules against up to five specific targets provided by AstraZeneca.
2006	Par pharmaceutical companies, Inc	Supply and distribution agreement to distribute an authorised generic version of metoprolol succinate extended-release tablets in US.
2006	Cerylid Biosciences	To acquire kinase inhibitators that have the potential to deliver a very effective anti-platelet therapy with minimal risk for bleeding complications.
2006	Pozen Inc	Global agreement to co-develop fixed-dose combinations utilising Pozen's proprietary formulation technology.
2006	Theravance, inc	Licensing agreement of a novel, short-acting intravenous anaesthetic/sedative agent.
2006	Abbott Laboratories	Co-develop and co-promote a cholesterol treatment in the US.
2006	Abraxis Bioscience Inc	To co-promote Abraxis' product Abraxane in the US.

2006	Dynavax Technologies Corp	To pursue opportunities in the field of Toll-like receptor 9 and COPD. (small molecules and biologics).
2006	Schering AG	To co-develop and jointly commercialise Schering AG's novel SERD. (research and licensing in the area of selective glucocorticoid receptor agonists).
2006	Cubist Pharmaceuticals	License agreement for the development and commercialisation of the anibiotic Cubicin.
2005	MedPointe	Distribution agreement for Zoming in the US.
2005	AtheroGenics Inc.	In-licensing agreement for global development and commercialisation of their anti-inflammatory cardiovascular candidate.
2005	Targacept Inc	Licensing and research collaboration.
2005	Schering AG	Research collaboration and cross licensing agreement in the area of selective glucocorticoid receptor agonists.
2005	Protherics Plc	Global development and commercialisation agreement for their anti-sepsis product CytoFab.
2004	CAT	Discovery alliance to generate monoclonal antibody therapeutics principally in inflammatory diseases. For AstraZeneca, this collaboration provides access to leading technology for the generation of fully human monoclonal antibodies for application across all relevant disease areas, working alongside a leading company in the field.
2003	Abgenix	Collaboration aims to discover fully human antibodies for the treatment of cancer.
2003	Array Biopharma Inc	Collaboration and in-licensing agreement
2002	Dyax Corp.	AstraZeneca's first venture in human monoclonal antibodies.
2001	Shanghai Jiaotong University on neurogenetics	To study the genetic basis of schizophrenia.
2001	NPS Pharmaceutical, Inc	The company focuses on CNS diseases mediated by the metabotropic gluatemate receptors.

(Source: AstraZeneca's corporate web site)

As with Pfizer, co-publication data retrieved from the ISI web of knowledge was used to provide an indication of AstraZeneca's engagement with universities and big pharma in the period 1980-2008. The investigation follows the same method as was used for Pfizer. Figure 4.10 illustrates that the number of publications has increased dramatically from the early nineties onwards. However, as with the representation of the R&D expenditure, the number of co-publications also signifies AstraZeneca as a supra firm in the pre-merger period: 1980-1999.

Figure 4.11



(sources: ISI Knowledge)

Figure 4.11 shows that the number of the AstraZeneca supra firm's publications increased sharply in the early nineties. In the meantime, co-publications with universities have increased proportionally, accounting always for approximately 50% of all publications. Also the collaboration with other big Pharma has produced a proportional number of co-publications, which kept them at around 5%-8% of all publications throughout.

- Acquisitions

Figure 4.7 shows that AZ has carried out a total of five acquisitions in the period 2001-2009, with one acquisition in 2006 and four in 2007. In terms of the completed acquisitions, AstraZeneca's acquisition of MedImmune was very significant in terms of its size. According to Sahoo (2008), the price paid, i.e. $15.2 bn, accounts for the single largest pharma-biotechnology acquisition by a wide margin. To illustrate the price, although MedImmune's annualized 2007 revenues exceeded $1.4 bn, the all-cash purchase price represented a high 63 times the midpoint of the company's earnings and about 10

times its revenues. The high price was the result of strong competitive bidding for MedImmune.

Table 4.7: R&D expenditure related to acquisitions in the period 2001-2009 – Astrazeneca

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of completed acquisitions	0**	0*	0*	0*	0*	1	4	0*	0*
Value of completed acquisitions (in $m)	44	0*	0*	0*	0*	1,148	14,891	0*	0*

(Source: AstraZeneca's annual reports)

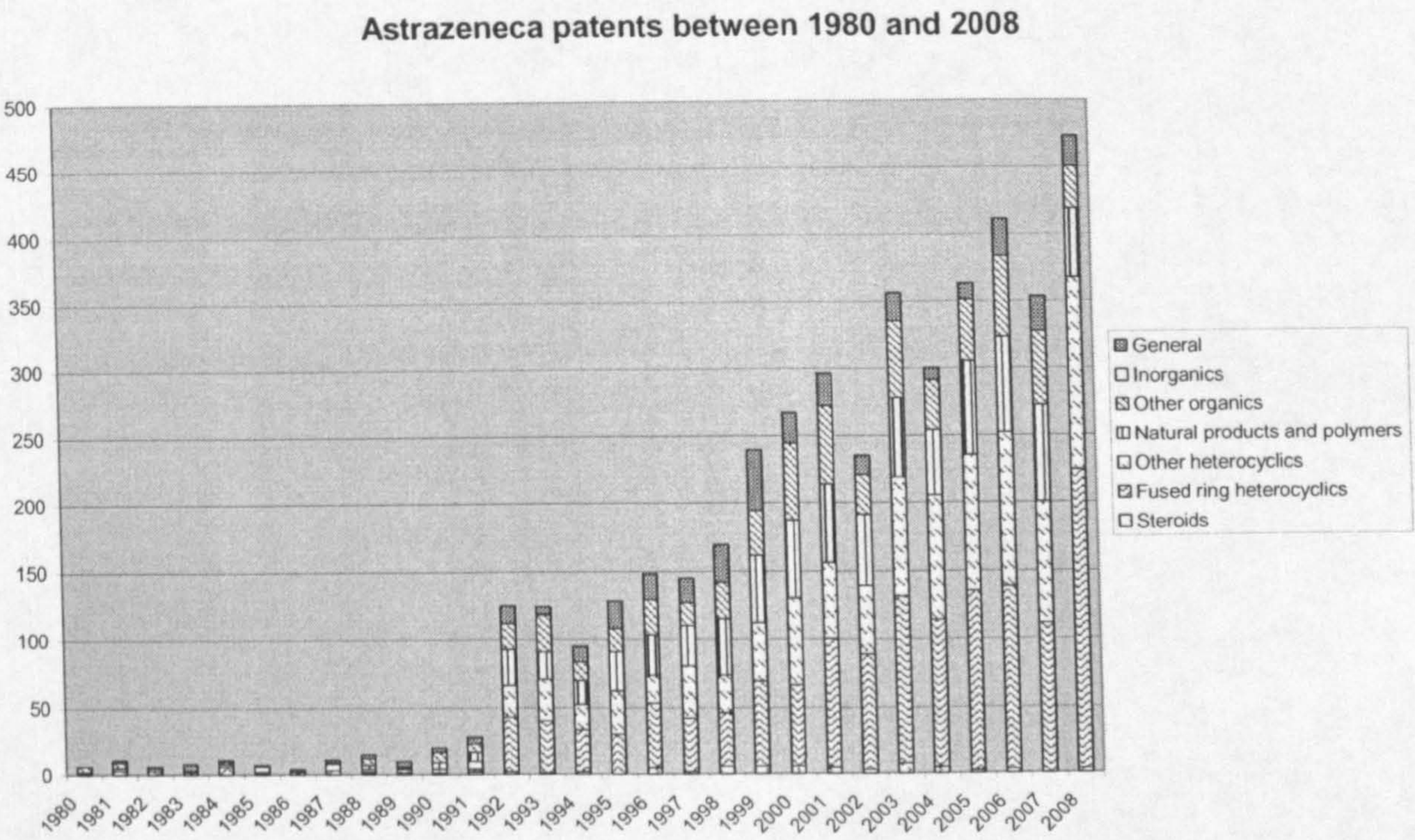
*nil is the correct figure
** "there were no significant business acquisitions" (p.78, AstraZeneca's 2001 annual report)

Innovation

Also in the case of AstraZeneca, the number of patents was traced using the Derwent database for the period 1980-2008. Given the merger in 1999, the only way to obtain an insight into the number of patents that AstraZeneca has filed over time is to regard AstraZeneca as a supra firm before the merger.

The findings are illustrated in the chart in Figure 4.12 and show that the Astrazeneca supra firm has produced a steadily increasing number of patents since the early nineties, with almost four times the patents of the early nineties in the last years. All along, the patents in their respective groups have changed their respective proportions, resulting in a modified mix.

Figure 4.12



(Source: Derwent)

- Number of drugs deriving from the different firm strategies

In the case of AstraZeneca, tracing the number of drugs deriving from the different knowledge acquisition strategies was easier than in respect to Pfizer, as not only the sources of the in-licensed drugs were indicated but the key drugs brought in by Astra AB and Zeneca Plc were indicated on their home page and double checked with the Thomson Pharma database. Putting these sources of information together enabled the production of Table 4.8 and Figure 4.13.

Table 4.8 illustrates not only that most of the drugs derive from either Astra or Zeneca, and hence are quite old, but also that AstraZeneca has not launched any new drugs since 2004. The fact that most of the drugs derive from the Astra AB and Zeneca Plc area constitutes the biggest limitation to the analysis, i.e. as was the case with Pfizer, there is less publicly available information regarding the older drugs and hence there is a probability that the

drugs come from external sources. However, as AstraZeneca has only merged once and given that the in-licence drugs are indicated in the annual reports, the only possibility is that some of the drugs would stem from some co-development collaborations.

Although the biggest proportion of revenues comes from in-house research, the proportion of revenue stemming from drugs originated by collaborations is significant, i.e. almost one fifth of the total revenues. The contribution to revenues stemming from drugs resulting from M&As is negligible, a result that is of particular interest given the huge amount of money spent on MedImmune.

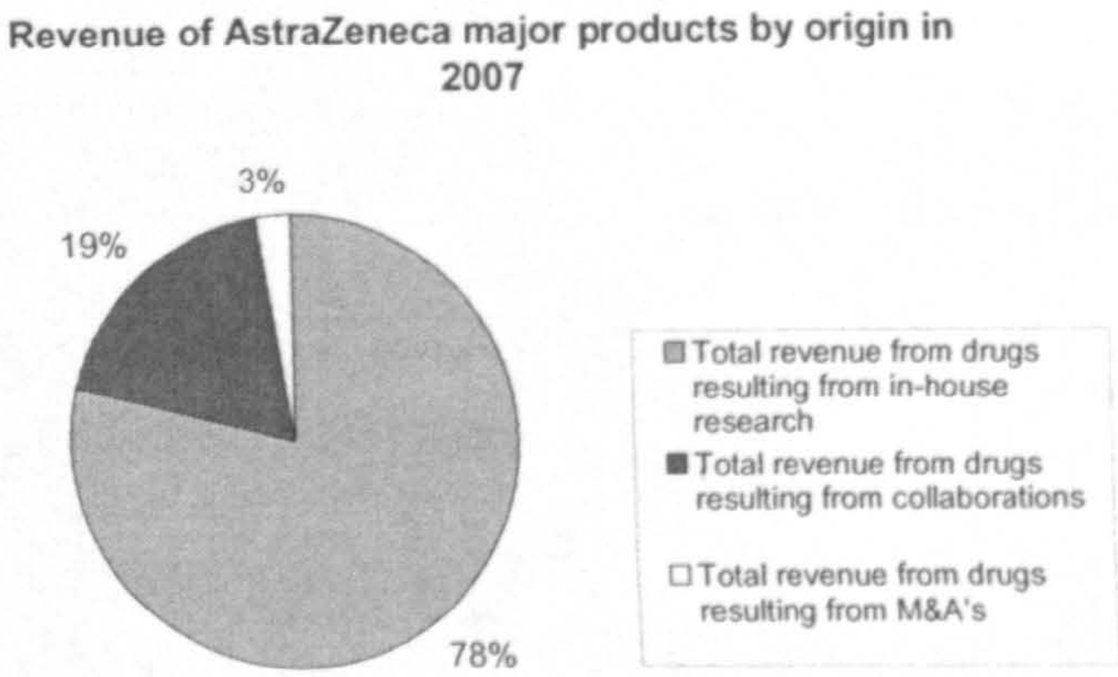
Table 4.8: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – Astrazeneca

	Revenues from each drug ($ millions)	
Drugs resulting from in-house research		
Seloken (Astra)	1,438	
Plendil (Astra)	271	
Losec (Astra)	1,143	
Pulmicort (Astra)	1,454	
Rhinocort (Astra)	354	
Oxis (Astra[5])	86	
Tenormin (Zeneca – Imperial Chemical Industries)	308	
Seroquel (Zeneca)	4,027	
Zomig (Zeneca)	434	
Diprivan (Zeneca - Imperial Chemical Industries)	263	
Zoladex (Zeneca)	1,104	
Casodex (Zeneca)	1,335	
Nolvadex (Zeneca)	833	
Arimidex (Zeneca)	1,730	
Accolate (Zeneca)	67	
Nexium (Astra, 2001)	5,216	
Symbiocort[6] (AZ, 2001)	1,575	
Falsodex (AZ, 2002)	214	
Iressa (AstraZeneca, 2002)	238	
Exanta (AstraZeneca, 2004)	N/A	
Total revenue from these drugs ($ millions)		22,090
Drugs resulting from collaborations		
Crestor[7] (licensed from Shinongi & Co, Ltd)	2,796	
Atacand[8] (licensed from Takeda Chemicals Industries, Ltd)	1,287	
Zestril (licensed from Merck & co, Inc)	295	
Abraxane[9] (licensed from Abraxis Bioscience Inc.)	62	
Merrem[10] (licensed from Dainippon Sumitomo Pharma Co., Ltd)	773	
Total revenue from these drugs ($ millions)		5,213
Number of drugs resulting from M&As		
Ethyol (MedImmune)	43	
Synagis (MedImmune)	618	
FluMist (Wyeth and MedImmune)	53	
Total revenue from these drugs ($ millions)		714

(source: AstraZeneca's annual report 2009 and Thomson-Pharma, database)

[5] In 1999 (same year as AZ merged), Oxis Turbuhaler is presented as a novel drug, held under the protection of Astra's Turbuhaler. From 2000 onwards, the drug seems to be presented as Oxis only.
[6] Symbiocort is announced as a new drug in the annual report of 2001. Given that there is a product called Symbiocort Turbuhaler is seems like also this product is a line extension of Astra's Turbuhaler.
[7] Crestor obtained FDA approval in 2003.
[8] Atacand was developed in collaboration with Takeda Chemical Industries Ltd and was first launched in 1997. Atacand was of the key products of Astra AB.
[9] Abraxane obtained FDA approval in 2006.
[10] 2000

Figure 4.13



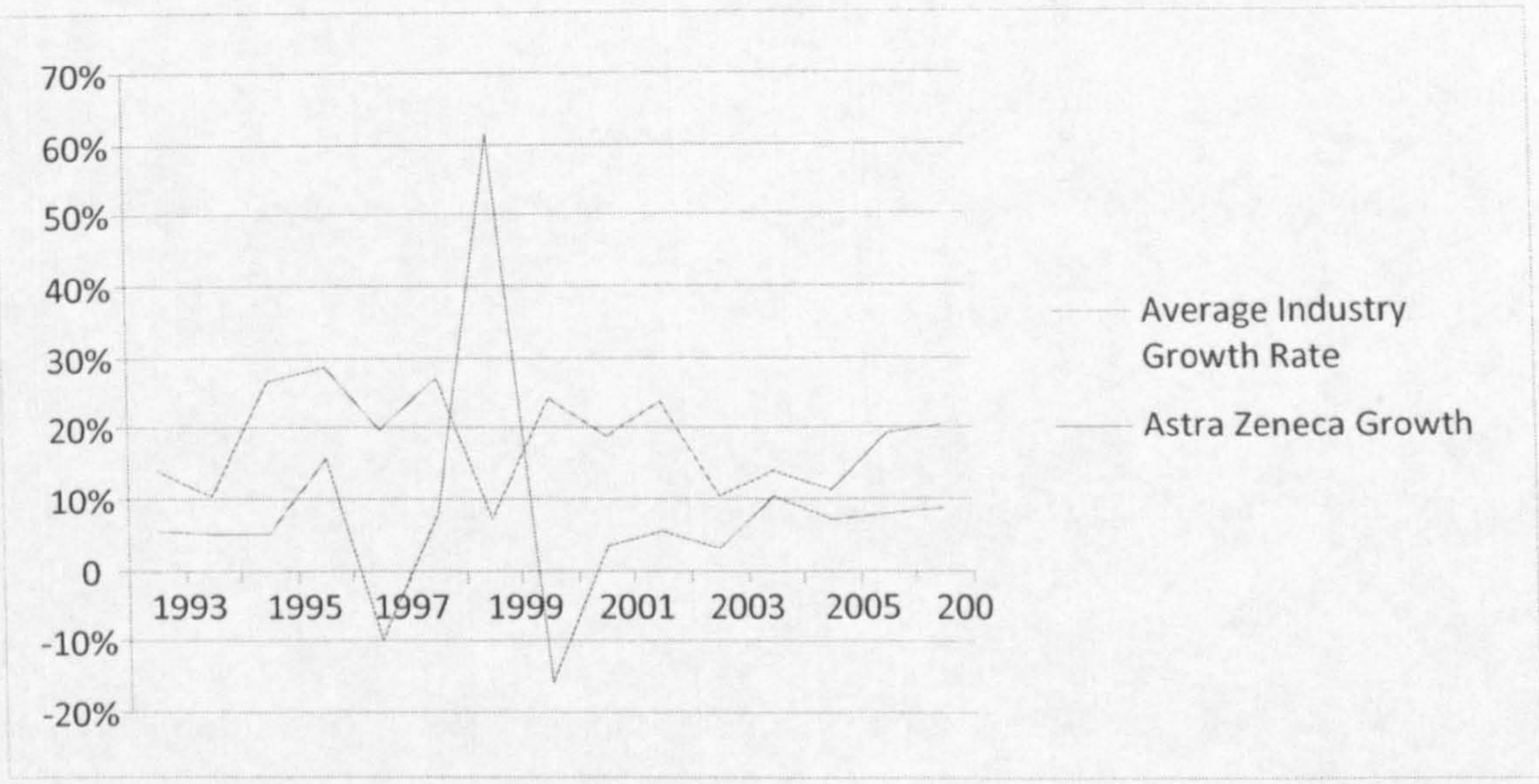
(source: AstraZeneca's annual report 2009)

Economic performance

- Growth

Figure 4.14 shows continuous growth throughout the period, except in 1997 and 2000. The firm shrank in 2000, a year after the 1999 merger, indicating that the steep expansion that coincided with the merger was not to last. Hence, although the post-merger drug portfolio four years after the merger creates a turnover that is almost four times higher than the turnover of four years before the merger, the merger has not improved the growth rate of the firm.

Figure 4.14



(Source: S&P database)

- Market value

AstraZeneca's share price has moved in line with the market (Figure 4.15), with the exception of two short periods when investors seem to have temporarily lost their confidence in the company, in 1999 and 2000[11]. Once again, this coincides with a major merger, i.e. Astra AB and Zeneca Plc.

Figure 4.15: AstraZeneca's market value 2003-2008

(Source: Nasdaq)

[11] NASDAQ reports a value of $625 for a very short period of time for Astrazeneca's share price in 2002. This value seems to be an error of the NASDAQ's records, as Astrazeneca's official website (Astrazeneca, 2008) does not report such a sharp increase and dramatic drop in value of its shares in the same period. For this reason the graph shown in Figure 4.14 refers to six years only, in order to preserve a readable scale of its axes.

Analysis 2: The importance of the different knowledge acquisition strategies for AstraZeneca's innovative success

Again, analysis two uses data in the first-level analysis to evaluate the effects the different knowledge acquisition strategies have had on the various firms' measures of innovation. Hence, time lags are taken into account.

By analysing the data on R&D (Figures 4.9 and 4.10), publications (Figure 4.11), patents (Figure 4.12), AstraZeneca's collaboration history (Table 4.6) and the firm's portfolio of drugs (Table 4.8), it appears that in coincidence with Pharma entering into biotechnology (early-nineties), R&D expenditures and collaborations increase significantly. Approximately six years after, the number of patents rises sharply. However, this resulted in just one new in-house originated drug a year in AstraZeneca's portfolio between 2001 and 2004, with a striking absence of new drugs since then.

As seen above, documents confirm that Zeneca formed, in the 1990s, a collaboration agreement with Incyte Pharmaceuticals to acquire knowledge in genomics. However, similarly to the case of Pfizer, none of AstraZeneca's portfolio of drugs can be ascribed to this collaboration, as all the drugs are in-licensed from various other firms. In fact, in-licensed drugs still account for approximately 50% of the revenues from drugs introduced in the new millennium.

Hence, the evaluation of AstraZeneca's innovation confirms what was found in the Pfizer case; collaborations do appear to have created value, but little evidence is found that collaborations have enabled the firm to *create* innovation or to build new capabilities.

On the other hand, AstraZeneca has carried out collaborations as a strategy to enter into biotechnology, by entering into agreements with two different firms to acquire knowledge

in MABs. An in-depth evaluation of the effects of these collaborations on AZ's innovation and capability building will be presented in chapter 6.

As with Pfizer, the time since the AstraZeneca merger is too short to fully evaluate its effects on the firm's innovative performance, i.e. given that it takes approximately 11 years to produce a drug, it is expected to see some drugs from next year onwards. However, when evaluating the R&D cost, the number of publications and the number of patents, all the measures go up after the merger. This is particularly evident for the number of patents, which rises sharply after the merger and reaches its highest point in 2008. This trend is clearly the opposite of what is happening in Pfizer. In the same way as Pfizer, however, the cost per patent after the merger has gone up three times since the years before the merger.

4.2.3 GSK

GlaxoSmithKline (GSK) is the result of a series of mergers that culminated with the merger between Glaxo-Wellcome Plc and Smithkline Beecham Plc in 2000.

Prior to that, SmithKline had merged in 1982 and 1989, respectively with Beckman Instruments Inc and Beecham. Glaxo-Wellcome Plc, on the other hand, was a result of the merger between Glaxo Plc and Wellcome Plc in 1995. Appendix A gives more complete information about the different mergers.

Analysis 1: Reliance on knowledge acquisition strategies, innovative success and economic performance

In the same way as the above firms, analysis one uses document- and database analyses to create a quantitative picture of GSK's reliance on different firm strategies, its innovation and its economic performance over time.

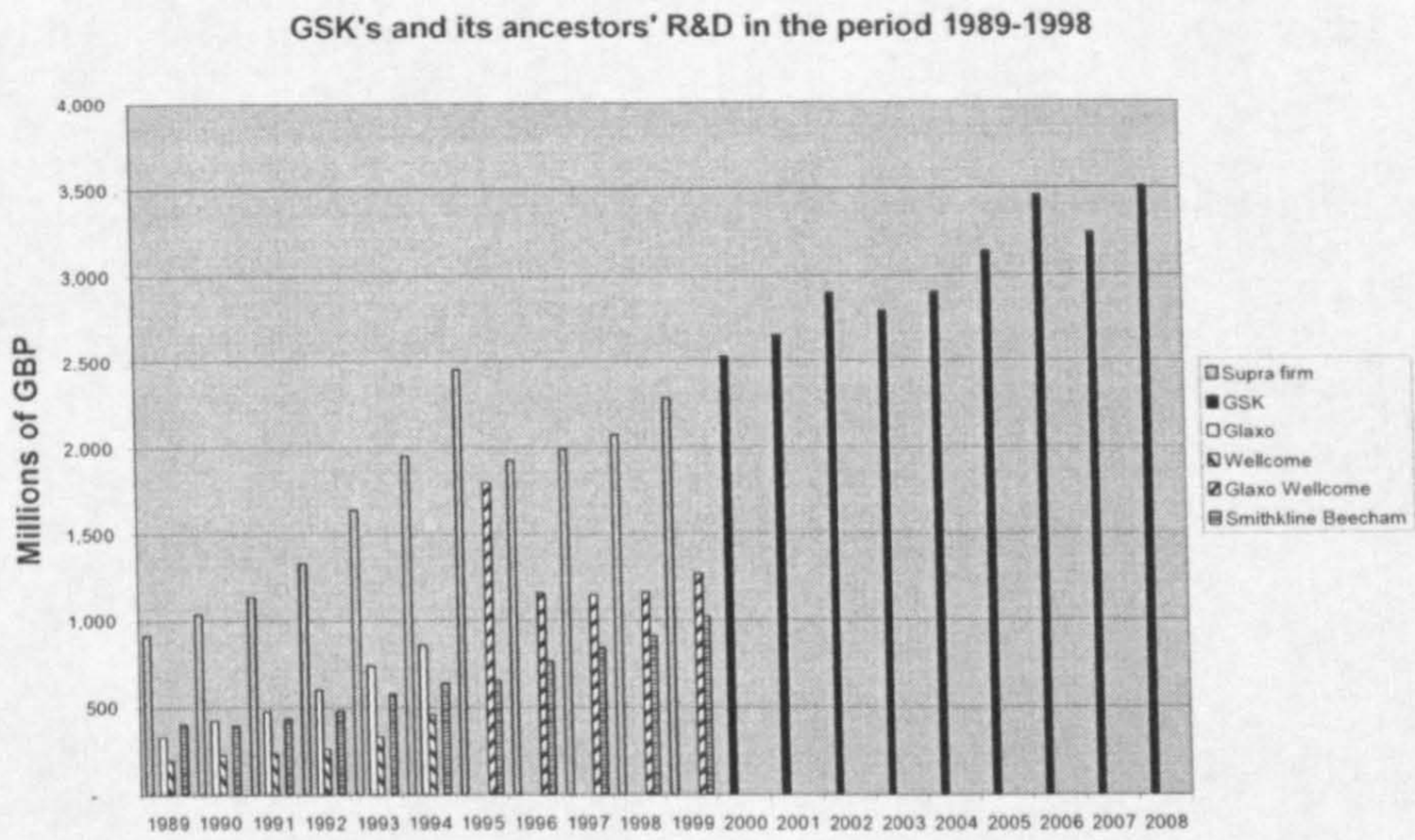
Firm strategies

- In-house R&D

Also for GSK R&D data was collected from its 10-K reports and R&D data for the ancestor firms were collected from Bloomberg. In order to obtain data for the same period as for Pfizer and AstraZeneca (i.e. 1989-2008), data on R&D expenditure had to be collected both for Glaxo-Wellcome in the period of their merger, i.e. in the period 1995-2000, whilst the R&D expenditure had to be obtained separately for Glaxo Plc and Wellcome Plc in the period before their merger, i.e. 1989-1995. Data on Smithkline Beecham R&D expenditure was collected for the entire pre-merger period taken account of in this study, i.e. 1989-2000. As was the case with AstraZeneca, given the fact that GSK is a result of the merger between Glaxo-Wellcome and Smithkline Beecham in 2000, the only way to understand GSK's reliance on R&D is to treat GSK as a supra firm in the pre-merger period.

The chart in Figure 4.16 shows that GSK has multiplied its R&D three and half times, as the GSK supra firm, in the last twenty years. The increase has been steady (almost on a straight line) all along, even during and after the main merger. Figure 4.16's values are nominal.

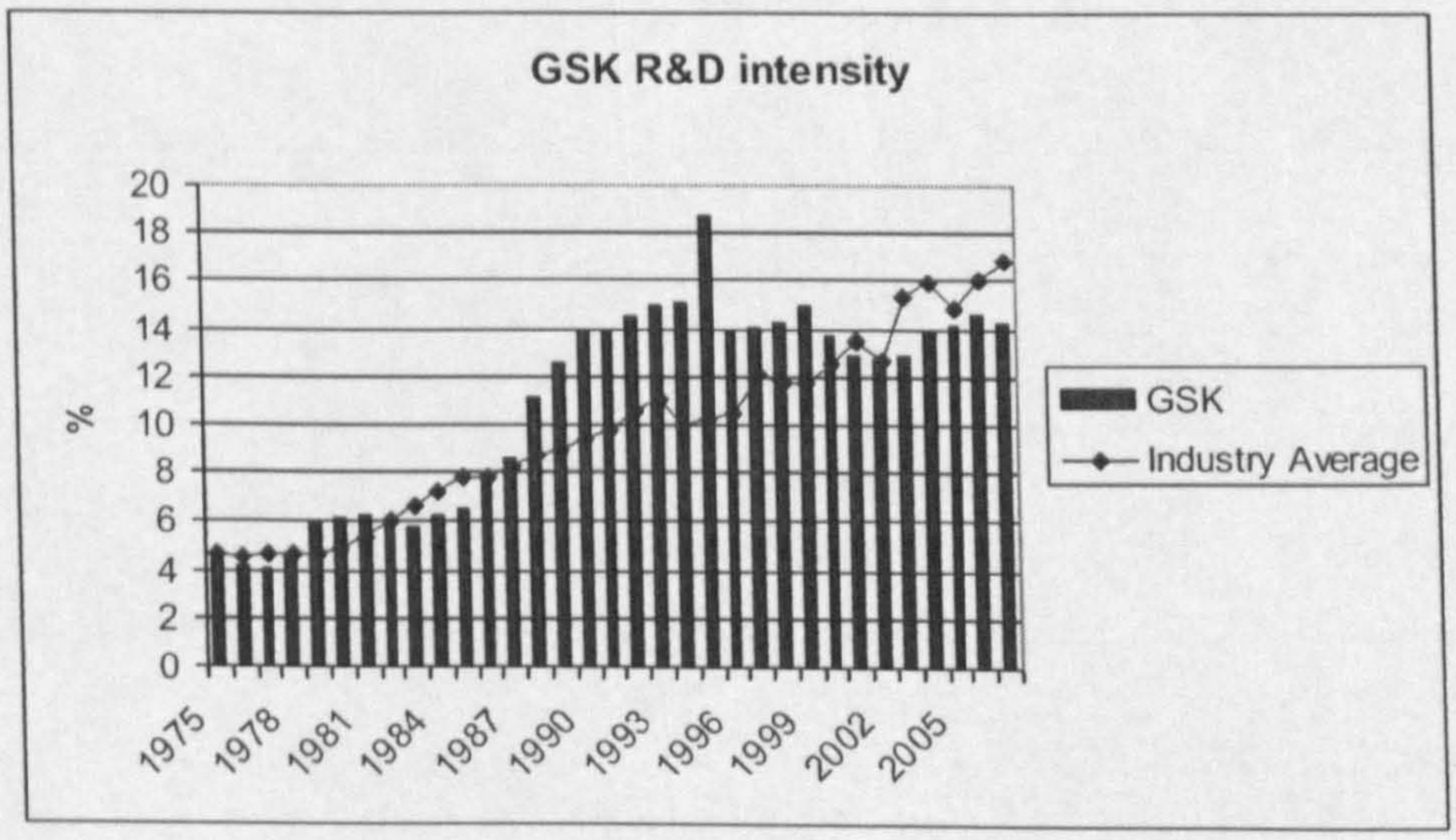
Figure 4.16



(Source: GSK's 10-K reports and Bloomberg)

The chart in Figure 4.17 shows that GSK's R&D intensity was significantly higher than the industry average between 1989 and 2000. In this period the peak was reached in 1996, after which GSK's R&D intensity declined to the extent that it has been lower than the industry average ever since 2000.

Figure 4.17



(S&P database)

- Number of collaborations

Table 4.9: R&D expenditure related to collaborations in the period 2001-2009 – GSK

The data shown in Table 4.9 illustrate that in the last decade, GSK has constantly initiated new collaborations. These peaked in 2001 and in 2006, and have never gone below three new collaborations per year.

	2001	2002	2003	2004	2005	2006	2007	2008	2009
Number of new collaborations*	11	8	6	3	5	11	9	4	5

(Source: GSK's annual reports)

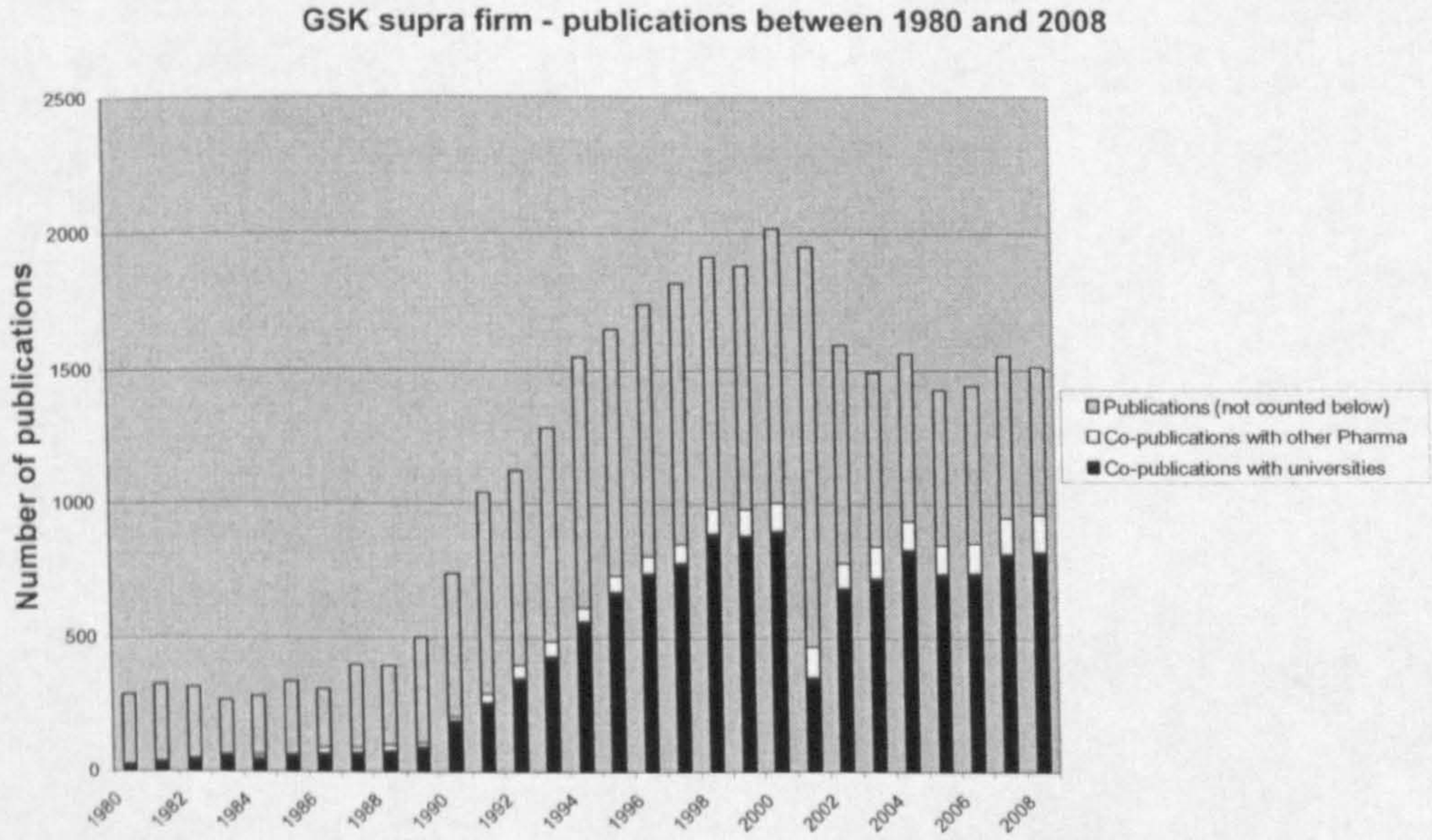
***these are an underestimation of the total, but represent the most significant collaborations**

Publication data from ISI web of knowledge was used also to indicate GSK's interactions with universities and the top 15 pharma firms. As with the R&D data, the publication data is presented as GSK supra firm before the merger between Glaxo-Wellcome and SmithKline Beecham *in 2000, which means that Glaxo-Wellcome's co-publications with* universities and the big pharma firms were collected in the period 1995-2000, whilst Glaxo and Wellcome's co-publications with the two groups were collected separately in the period 1980-2000. Smithkline Beecham's data were collected in the period 1989-2000.

The findings are presented in the chart in Figure 4.18 and show that in the ten years preceding the main merger, the number of GSK supra firm's publications has increased more than seven times, to reach its peak in the year of the merger. After the merger the number of publications drops significantly, to settle at the same level as six/seven years before the merger. In the meantime, the co-publications with universities have steadily increased more than proportionally, from less than 15% of all publications in the early

eighties to more than 50% in the most recent years. On the other hand, collaboration with other big Pharma has produced a proportional number of co-publications, which kept them at around 5% of all publications, until the beginning of the new millennium, when they started a slightly more marked increase, reaching 9% of the total in the last two years.

Figure 4.18



(Source: ISI Knowledge)

- Number of acquisitions

The data shown in Table 4.10 illustrate that in the second part of the last decade GSK has dramatically intensified its acquisition strategy; with the trend showing that acquisitions peak every second year, the average investment per year has significantly increased.

Table 4.10: R&D expenditure related to acquisitions in the period 2001-2009 – GSK

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Number of completed acquisitions	2	2	2	2	6	5	3	4	8
Value of completed acquisitions (in $m)	657	20	12	297	1,026	273	1,027	454	2,792

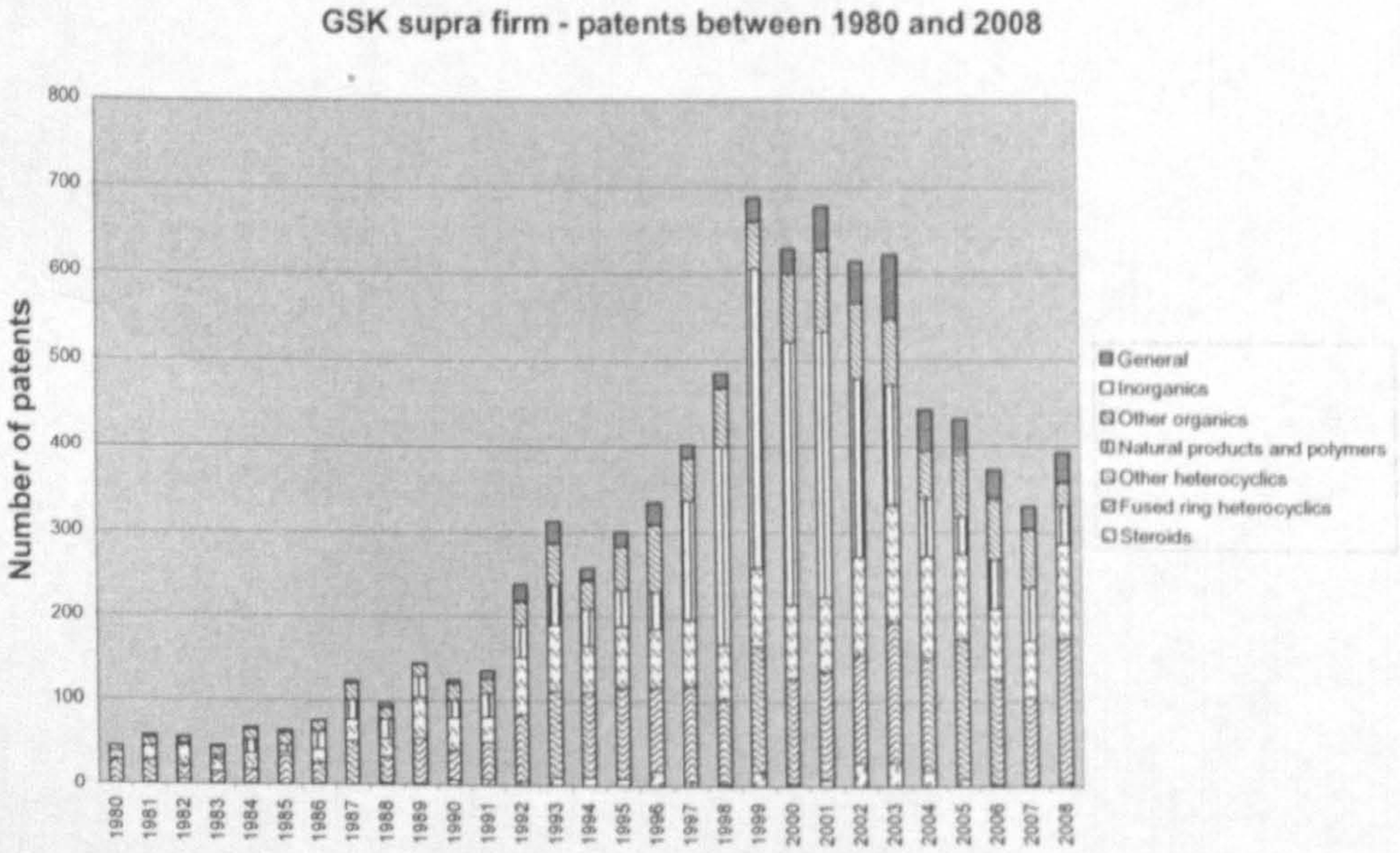
(Source: GSK's annual reports)

Innovation

Again, the Derwent database was used to trace GSK's number of patents in the period 1980-2008 and, as was the case with AstraZeneca, GSK is treated as a supra firm before the merger between Glaxo-Wellcome and SmithKline Beecham in 2000.

The results are presented in the chart in Figure 4.19 and show that in the ten years preceding the main merger, the number of GSK supra firm's patents has increased more than fifteen times, to reach its peak in the year before the merger. However, three years after the merger the number of patents dropped significantly, to settle at the same level as four years before the merger. All along, the patents in their respective groups have grown almost proportionally, resulting in slight modifications of their mix.

Figure 4.19



(Source: Derwent)

- Number of drugs deriving from the different firm strategies

A first indication of the number of drugs stemming from external sources was found on the GSK homepage, stating that 40% of its products derived from in-licensing in 2008.

Table 4.11 illustrates that most of the revenues derive from drugs that have been developed in house, rather than having been acquired or resulting from collaborations. However, the vast majority of new drugs come from collaborations and from having been acquired. This information was retrieved from GSK's annual reports and the Thomson Pharma database.

Table 4.11: Number of drugs stemming from the different firm strategies: in-house R&D, collaborations and M&As, and the revenues attached to them – GSK

	Revenues from each drug ($ millions)	
Drugs resulting from in-house research		
Augmentin (GSK)	587	
Avandia (SmithKline Beecham Plc)	805	
Avodart (2003 – Glaxo Wellcome)	399	
Boostrix (2006)	70	
Combivir (under licence from Shire BioChem)	433	
Flixonase/Flonase (Glaxo Wellcome)	186	
Flixotide/Flovent (Glaxo Wellcome)	677	
Flu pandemic	66	
Fluarix (SmithKline Beecham)	215	
Hepatitis	665	
Hycamtin (SmithKline Beecham)	140	
Imigran/mitrex (Glaxo Wellcome)	687	
Infanrix (SmithKline Beecham)	682	
Lamictal (Glaxo Wellcoem)	926	
Requip (2008 – SmithKline Beecham)	266	
Seretide (Glaxo Wellcome)	4,137	
Trizivir (Glaxo Wellcome)	212	
Tyverb (2007 – GSK)	102	
Wellbutrin (Glaxo Wellcome)	342	
Ziagen (Glaxo Wellcome)	106	
Zofran (Glaxo Wellcome)	110	
Total revenue from these drugs ($ millions)		11,813
Drugs resulting from collaborations		
Agenerase (Vertex Pharmaceutical Inc.)	160	
Bonviva (2005 – Roche)	237	
Cervarix (2007 – Medimmune)	125	
Coreg (2008 – Roche)	203	
Epivir (Glaxo Wellcome and Shire BioChem)	139	
Epzicom (2005 – Pfizer[12])	442	
Levitra (2003 – Bayer AG)	60	
Relenza (Biota Holdings Ltd)	57	
Rotarix (2007 – Celldex Therapeutics Inc.)	167	
Serevent (Almirall Prodesfarma SA[13])	263	
Seroxat/Paxil (Novo Nordisk A/S)	514	
Treximet (2008 – Pozen Inc.)	25	
Valtrex (GSK – Advantagene Inc.)	1,195	
Vesicare (2005 – Yamanouchi Pharmaceutical Co. Ltd)	71	
Zefix (Shire BioChem Inc.)	188	
Total revenue from these drugs ($ millions)		3,846
Drugs that have been acquired		
Arixtra (2005 – Sanofi-Synthelabo)	170	
Fraxiparine (2005 - Sanofi-Synthelabo)	226	
Lovaza (2008 – Pronova BioPharma ASA)	290	
Total revenue from these drugs ($ millions)		686
Grand total		16,345

(Source: GSK's annual report 2009 and Thomson-Pharma, database)

[12] Partnering company
[13] Partnering company

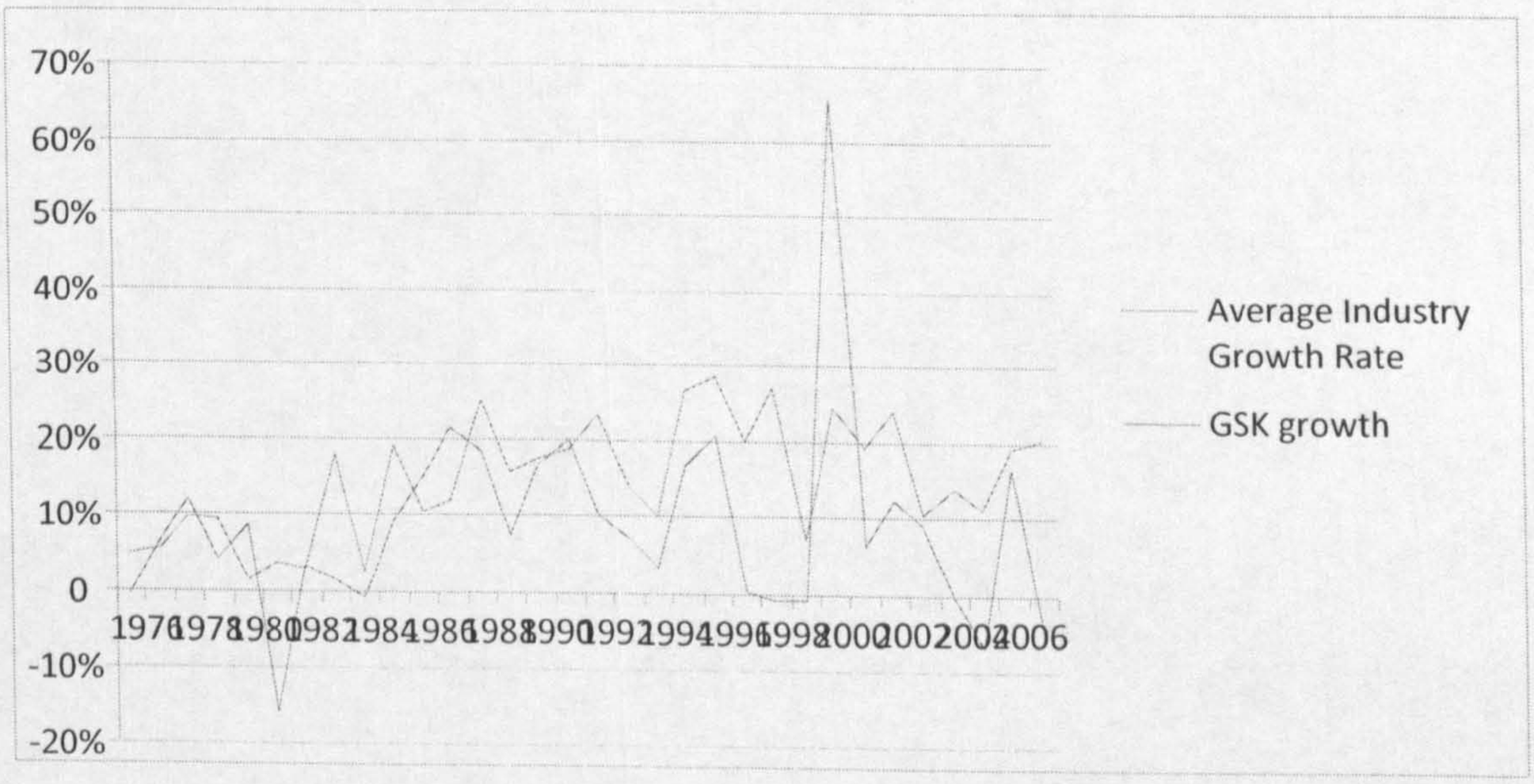
Economic performance

As with the other companies, growth and market value used as measures for GSK's economic performance.

- Growth

The chart in Figure 4.20 shows that GSK increased its size for most of the years in the period between the mid seventies and 2007, with the exceptions of the years 1981, 1998, 1999, 2004, 2005 and 2007. However, GSK's growth has consistently been lower than the industry average, with the notable exception of the peak in the year of its main merger (i.e. 2000).

Figure 4.20



(S&P database)

- Market value

Finally, GSK's share price trend (Figure 4.21) shows that, if a negative effect has been suffered by its shares after the major merger between Glaxo-Wellcome Plc and Smithkline Beecham Plc, this has been short in time and minor in value.

Figure 4.21: GSK's market value 1998-2008

(Source: Nasdaq)

Analysis 2: The importance of the different knowledge acquisition strategies for GSK's innovative success

As with the other companies, analysis two uses data in the first-level analysis to evaluate the effects the different knowledge acquisition strategies have had on GSK's measures of innovation. Hence, time lags are taken into account.

By analysing the data on R&D (Figures 4.16 and 4.17), publications (Figure 4.18), patents (Figure 4.19), and GSK's portfolio of drugs (Table 4.11), it appears that coincidentally with Pharma entering into biotechnology (early-nineties), R&D expenditures and collaborations increase significantly. Approximately six years after, the number of patents rises sharply, only to decline again two to three years after the new millennium merger. However, this resulted in just three new in-house originated drugs being added to GSK's portfolio since 2003, whilst more than ten were either acquired or resulted from collaborations in the same period.

Hence, the evaluation of GSK's innovation shows that the wide amount of collaborations appears to have impacted very little on GSK's ability to *create* innovation or to build new capabilities. Nevertheless, collaborations have been the main source of revenue since the merger.

As with Pfizer and AstraZeneca, the period since the GSK merger does not provide sufficient time to evaluate the effects of the merger on GSK's innovative capabilities. However, comparing GSK's R&D expenditure, its number of publications and its number of patents, it is striking to note that despite the fact that R&D expenditure rising steadily after the merger, and the numbers of publications and patents reaching a peak around the time of the merger, both the number of publications and the number of patents fell to reach their lowest points in 2006, the same level as 11 years before. However, calculating the cost per patent with a six year lag, the result is similar to both Pfizer and AstraZeneca, as it has increased by almost three times.

4.3 Cross-case analysis

With respect to the three different strategies considered in this study, the following summary remarks can be drawn from the data analysed above.

The last twenty years have shown that for each of the three firms, here regarded as supra firms, R&D has significantly increased. Although the firms show different paces of increase, the common aspect is that they all increased their reliance on R&D. However, it emerges from the analysis that the firms' reliance on R&D has reacted differently to major mergers where, for example, Pfizer's merger has boosted its R&D, but only temporarily, whilst GSK has kept R&D growing at the same pace before and after the merger, as has AstraZeneca.

As expected, the three firms have, since the mid-nineties, spent a higher proportion of their revenues on R&D than the average for the industry. However, both GSK and AstraZeneca's research intensity went below the industry average in more recent years, whilst Pfizer kept its research intensity just above the industry average, (see Figures 4.2, 4.10 and 4.17).

The co-publication data shows that the firms' reliance on collaborations with other big pharma and universities has also increased in all firms. All three firms, though, preferred to rely more and earlier on collaborations with universities rather than with other big pharma, respectively in the beginning and the end of the nineties.

The fact that the co-authored publications seem to increase around the new millennium, a period which is characterised by R&D inefficiency in the industry, illustrates the need to share knowledge, even between the major pharmaceutical firms. The growing interaction observed between the major players seems to illustrate that the big pharma firms are more prone to talk to each other than previously.

In addition to the selected firms being the result of mergers, which took place around the new millennium, they all have increasingly carried out further acquisitions, of which the biggest by far was carried out by AstraZeneca when acquiring MedImmune in 2007.

The effects of these three strategies have been diverging. Despite the increase in R&D over the years, the number of patents has gone down in the new millennium for both Pfizer and GSK, and AstraZeneca has not launched any new drugs since 2004. It is important to note that all the selected firms have established their existing merger structure around the year 2000. Although it is too early to evaluate the effects the mergers have had on the firms' innovative capabilities, the financial information analysed showed, fairly consistently

across the three firms, a lack of success after the mergers. In the case of all the selected firms, the firms' growth was negatively affected by the mergers and, in the case of Pfizer and AstraZeneca, the market value was also negatively affected. This is confirmed by independent industry analysts, who highlight that the wave of M&As did not create value for shareholders in the pharmaceutical sector (Saigol, 2008). This is further evidenced by empirical results showing that merged companies have on average worse performances than non-merging firms (Ornaghi, 2008).

An intriguing result has emerged consistently from the analysis of the three firms; the collaborations have indeed created value and enhanced the firms' portfolio of drugs, but do not seem to have improved their ability to build innovative capabilities. This is a question that can only be addressed through more in-depth study, as pursued in the next two chapters with the cross-case and case study.

Chapter 5:

Cross-case interviews

5.1 Introduction

This chapter seeks primarily to present the findings obtained when investigating the importance of R&D and collaborations for innovation and capability building (i.e. *research question one*) through the semi-structured interviews, carried out across the sample firms, i.e. in section 5.2. However, given the fact that cross-case interviews were also used to pilot the investigation into the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge (i.e. *research question two*) the subsequent section 5.3 will present the key findings obtained through this investigation. The chapter ends with a summary of the key findings of both the sections 5.4.

5.2. The importance of R&D and collaboration for innovation and capability building

Having used interviews to investigate the importance of R&D and collaborations for innovation and capability building, this section seeks firstly to present the interviewees' initial perceptions of the distinctive effects of the different knowledge acquisition strategies, and then to use the specific findings obtained through the interviews to provide a deeper understanding of these perceptions. In order to obtain a fuller picture of the findings, the presentation seeks to indicate how the specific findings were obtained.

As seen in section 3.9, given that the findings obtained in the cross-case interviews were so similar, it was possible to present the findings together rather than on a case-by-case basis. In addition to the assumption that presenting the data together would provide a deeper understanding of the importance of R&D and collaborations for innovation and capability building, this section seeks to enrich the quality of the interview data by including some findings obtained through interviews carried out outside these firms as well as drawing parallels between the interview data and the findings obtained through the archival analysis. In terms of the interviews carried out outside the selected firms, specific findings come from a Senior Manager at Merck, two consultants and two university professors.

5.2.1 Interviewees' perceptions of the distinctive importance R&D and collaborations have for innovation and capability building.

Whilst the initial aim of the interviews was to obtain a rich understanding of the distinctive importance R&D and collaborations have for innovation and capability building, the extensive reliance on R&D, collaborations and M&As revealed by the archival analysis triggered a broader approach at the start of the interviews, asking how important they regard these different knowledge acquisitions for their firms' innovative success. Starting the interviews by inquiring into the effects of all the different knowledge acquisition strategies was thought to provide a more coherent picture of, as well as a basis to investigate, the relative importance of the different knowledge acquisition strategies. With this as a starting point, it is interesting to note that there was a consensus among the different interviewees that collaboration is increasingly the most important knowledge acquisition strategy. The perception of the importance of in-house R&D and M&As was, on the other hand, more mixed. The following seeks to present a deeper account of the interviewees' perceptions of the importance of the different knowledge acquisition

strategies, as well as the arguments underpinning their views. The different knowledge acquisition strategies will be presented in separate sections.

Collaborations

The finding that the interviewees were uniformly positive about the growing importance of collaboration is in direct line with the archival analysis, showing that most of the sample firms' recent drugs stem from collaborations. This section seeks to firstly illustrate the importance the interviewees attributed to collaborations today and the increasing reliance on collaborations over time, and then, by drawing on the interview data across the firms, to provide a deeper insight into the reasons for the growing importance of this knowledge acquisition strategy.

The importance of collaborations is illustrated in the following statements:

"Collaborations are absolutely essential" (Senior Manager, Alliance Management AZ)

"Collaborations are indeed very, very important" (Senior Manager, Alliance Management, GSK)

The importance of collaborations was further highlighted in a public talk held by the CEO of AstraZeneca, where he started the talk saying: *"I think that partnerships and alliances [are] what it is [all] about. I think it is about trying to find new ways, different ways to harness energy, bringing together different kinds of thinking to create something new. [This], in our business, [means] something that is of value to the health care system".* (David Brennan, CEO, AZ).

Furthermore, in an in-depth interview, a Senior Manager in Alliance Management at AstraZeneca illustrated the growing importance of collaborations, as he sees the reliance on collaborations as a gradual evolution in the pharmaceutical industry; the major

pharmaceutical firms would rely 100% on their internal capabilities in the 1960s, whilst at the moment 50% of the firms' products are externally 'sourced'.

The most cited reasons for the increasing importance of collaborations in the sample firms are the scope of research, and change in the knowledge base and regulation, as illustrated below.

Interviewees both at Merck and AstraZeneca promote the growing range of research as a key factor for increasing reliance on collaborations, as illustrated in the following statement: *"The academic life science research - the medical research has grown - the biotechnology industry has been born and developed within my working life time. None of that stuff was on a map thirty years ago. It is all there now. Those people are doing work, which is valuable to AstraZeneca and we want to partner with them".*

The CEO of AstraZeneca stated in a public talk that *"Research has shifted to a somehow new arena. Products that are successful on today's market place are a result of research that took place between 1970 and 1990. While work in that area [of research] continues to some degree, it has been pretty well harvested and the new areas that have emerged [are] really biologics and genomics. We're working through [those] to figure out how to produce personalised medicine: a world of enormous promise for the future".*

The growing scope of research and the change of the knowledge base seem to have clear implications for big pharma firms, with the following statement reinforcing the AstraZeneca CEO's statement that the traditional knowledge base is a fairly harvested area: *"we used to be the best at anti-hormonals. We don't believe [that] that is where the business needs to be, [hence] we have a choice [that] we can either invest internally in*

new areas or we can partner. What is interesting is that, increasingly,[...] we choose to partner".

A Senior Manager in R&D at AstraZeneca, on the other hand, raises an implication of the range of research now being so large: *"you can't possibly, in today's world, have the whole range of science and technologies that you need in the different therapy areas to remain competitive. No pharma company is big enough to do that."*

To illustrate the range of research, a Senior Manager in Alliance Management at both AstraZeneca and Merck, highlighted that 99% of the research happens outside the boundaries of their firms. Moreover, being asked to comment upon the statement made by the CEO of AstraZeneca (i.e. *"collaborations is what it is all about..."*), the Director of Alliance Management Support Office at AstraZeneca referred to the same percentage, saying: *"it would be a very brave CEO who would only be interested in that 1% of the research"* [carried out at AstraZeneca].

Another much-cited reason for the increasing reliance on collaboration is the stricter regulatory environment, as illustrated in the quote below made by a Senior Manager in Alliance Management at AZ: "*we use collaborations to help us through the regulatory pressures on the industry*".

In-house R&D

In addition to a common perception among the sample firms that their respective firm only performs 1% of the world's research, the interviewees at the sample firms admitted that they had become more inefficient in their innovation of new drugs over time, as illustrated in the following statement:

[...] *"there are some shocking facts out there. One that always gets quoted is that: the productivity per dollar has fallen steadily since the 1960s, the patents per dollar is dropping and the number of drugs that finally get through regulatory agencies is dropping year on year etc"* [..].(Senior Manager in Alliance Management, AZ)

The consequence of the drop in innovation is illustrated in the quote below:

"The industry is in a period of contraction and in approximately four years will see a further >$120 billion loss of patented products. Even if the smaller companies were swallowed at zero cost by the larger companies the pipelines of these smaller companies would leave a gap of $80 billion in revenue" (Senior Manager, Merck)

Reflecting upon the consequences of big pharma's inefficiency in producing new drugs, a Senior Manager in Alliance Management at Merck stated: *"some critics claim that big pharma now is only focusing on life cycle management of our products...and to some extent that is true".*

Though expressing concerns regarding the severe R&D inefficiency that big pharma is undergoing at the moment, a Head of R&D at GSK highlighted that there is an inherent vulnerability of in-house R&D, pointing to periods where not one of the products GSK had put on the market was developed in-house. When talking about this, the Head of R&D explained that GSK has seen cyclical phases in terms of their ability to innovate, with *"huge deserts"* between periods when R&D has been able to deliver. The Head of R&D sought to explain the vulnerability of R&D metaphorically: *"it shows you [that] you can go [on] for years...and if you're paddling the wrong canoe, you are paddling the wrong canoe!"*

Yet other interviewees, particularly at AZ, emphasised that most of their drugs come from in-house research. Although this is true, the archival analysis shows that in the case of AZ, these drugs are quite old.

M&As

The above statement, regarding the 'vulnerability of R&D to innovate', seems to lie at the heart of the motivation for the mega-merger strategy carried out at all the sample firms. In particular, a Senior Manager at GSK revealed that Glaxo Wellcome's struggle to replace expired 'blockbuster' drugs (i.e. Zantak and Zovirax) was a key reason driving the company to merge with Smithkline Beecham in 2000. Although this view was more pronounced in the interviews carried out at GSK, several interviewees at the other sample firms admitted their firms were experiencing patent expiries and that the mergers had served as 'quick additions' of new drugs. These findings are directly in line with the document analysis, showing that all the sample firms had gained a substantial increase of drugs through their mergers.

Interestingly, the interviews showed a clear gap between senior managers and scientists in terms of their optimism regarding the effects the mega-merger strategy has had on their innovative capabilities. Although pointing to the low share prices the firms had after the big mergers (illustrated for all the sample firms in the data analysis), Senior Managers both in R&D and Alliance Management highlighted the extensive time involved in settling into one firm, and the fact that the time elapsed since they had merged is not sufficient to evaluate the actual effects of the mega-merger strategy, as illustrated below:

"GSK is only now starting to find its own identity" (Head of R&D, GSK).

Scientists, on the other hand, held a more pessimistic view of this strategy's potential for acquiring knowledge and building innovative capabilities than those of their managers, as illustrated below:

"I do not trust that we'll become more innovative now having become twice as big!" (Scientist, GSK)

Though a varying degree of optimism towards the mega-merger strategy was evident, the interviewees proved more optimistic towards the single acquisitions carried out by their firms. An in-depth interview with a scientist at Pfizer revealed the following:

"Despite the fact that carrying out acquisitions might be a risky strategy, acquisitions have an immediate impact on the innovative capabilities of a therapeutic area". (Scientist, Pfizer)

"We have acquired world leading firms – of course this has the potential to improve our innovativeness!" (Senior Manager, AZ)

In summary, the fact that the interviewees were uniformly positive about the growing importance of collaborations, while highlighting that the firms are suffering R&D inefficiency, as well as indicating that the time since the mergers is not sufficient to fully evaluate the importance of the mega-mergers, shows that the interview data is directly in line with the archival analysis. Importantly, the confirmation that the time involved since the mega-mergers was too short to evaluate their effects made it natural to re-focus the remaining part of the interviews primarily on R&D and collaborations. Apart from section 5.2.6, the remainder of this chapter will consequently focus only on R&D and collaborations.

5.2.2 When does big pharma prefer to collaborate?

In order to further the understanding of the importance played by collaboration, the research sought to identify the context in which collaborations would be the most preferable option.

Interestingly, in the same way as the interviewees see the increasing reliance on collaborations as linked with the growing scope of research, most of the interviewees see collaborations as a way to enter new areas, as illustrated in this quote: *"you collaborate in those areas where you believe [that] either things are changing so fast or that your internal capability is not so strong"*.

A deeper insight into the choice of using collaborations for entering new areas was obtained in an interview with a Senior Manager in Alliance Management at AstraZeneca.

Referring directly to a competitor analysis on Merck, which had shown that Merck promotes a sort of ranking system in terms of areas in which the company seeks collaborations, i.e. the first priority being their therapeutic areas, then other similar areas, then areas where they do not hold prior skills, the Senior Manager was explicitly asked if AZ match the areas for partnering with their internal capabilities. As a direct response to this question, the senior manager in Alliance Management at AZ answered: *"that is not necessary relevant. What is crucial for our decision for when to collaborate is where we believe the business needs to be going"*. He then gave an example, which not only illustrates his first response but provides a deeper understanding of the rationale for choosing collaborations for entering new areas, *"for example, if we had no capability whatsoever in DNA repair ([in fact] we do, but if we didn't) and we became aware that DNA repair is where we needed to be, it [would be] much easier to go down the business*

development route and find a partner than it is to recruit one hundred people to build up a team and, you know, [it would] take two years before it starts to get its acts together".

When inquiring specifically into the key strategies for entering into biologics and genomics with Senior Managers at Pfizer, GSK and AstraZeneca, all of them confirmed that collaborations together with single acquisitions of small biotechnology firms had been the major strategies for entering this space. Whilst this is in direct line with the findings in the archival data, further interviews with a Senior Manager in Alliance Management at AstraZeneca and a scientist in Pfizer confirmed documentary evidence that their respective firms had formed collaborations with niche firms in the nineties in order to enter into genomics. Whilst Pfizer had entered into a six-pack alliance with ArQule, Aurora Biosciences Corp, Celera Genomics group, Evotec BioSystems AG, Incyte Genomics Inc and Neurogen Corp, Zeneca had entered three consecutive deals with well known US genomics company Incyte pharmaceuticals in the 1990s. As the research inquired more deeply into the reasons for Zeneca entering into collaboration with this company, the Senior Manager explained that this particular company had a substantial presence platform in the human genome and by collaborating with it, AZ gained *"early access to the human genome as it was unravelling".*

Interestingly, whilst Senior Managers emphasise the sample firms' efforts in obtaining early access into genomics and biologics through collaborations and acquisitions, a pharma consultant, on the other hand, claimed that big pharma firms were late-comers in this industry. The consultant claimed that the major pharmaceutical firms effectively ignored the importance of biotechnology in the 1980s and, as such, left universities and an increasing number of small firms to build on their capabilities in this area. By 'losing out' on the developments in biotechnology for an entire decade, the consultant stated that the

major pharmaceutical firms had no other option than to rely heavily on collaborations and acquisitions to acquire knowledge in biotechnology.

Though emphasising the importance of using collaborations for accessing newer areas, an in-depth interview with a director of Alliance Management at AstraZeneca on the use of collaborations revealed that the biggest group of collaborations in his area are focused on AstraZeneca's own products, as illustrated in the following statement: *"collaborations have two purposes: the first is finding out new areas or new targets and the second, and by far the biggest, is really to help you through the R&D on your own products"*. The director continued: *"every product we've got has been subject of one form of collaboration. It doesn't mean that we bought it from external sources; it is more likely we discovered it within our own R&D, but we collaborate around the products. We always collaborate on our products"*.

This finding – that all of AstraZeneca's products have been developed through collaborations – placed an even greater importance on collaborations than first anticipated. This showed the need for deeper insight into the types of collaborations pharma companies engage in to pursue the above purposes, what the exact frequencies are, the direction of the knowledge sharing between big pharma and the external collaborators, how valuable they are for the firms' innovation, and their potential for improving the firms' innovative capabilities.

5.2.3 Types of collaborations

There have previously been attempts to investigate the different types of collaborations in the pharmaceutical industry. As seen in the literature review, Atun *et al.* (2007) is one example, and holds that partnerships in the pharma industry cover a spectrum of different

types of collaborations, extending at one end from "arm's length's activities of transferring ready-to-use elements of a specific technology or pieces of equipment (similar to a license or consultancy agreement), to collaborative agreements in which a partner undertakes a specified piece of work (depending on whether they have defined the outcome or the problem); to joint ventures designed to solve a problem using combined resources, including reciprocal "in-sourcing" arrangements" (p. 334).

Although Atun's framework gives an overview of the range of collaborative activities taking place in the industry, this research sought firstly to better understand what types of collaborations belong to the middle group, i.e. collaborative agreements, and secondly to understand the frequencies of the different collaborations as well as their preferred partners. The findings, based on interviews with representatives from Alliance Management at AstraZeneca, Merck and GSK, are classified into two distinctive groups; industry-academic collaborations on the one hand, and big pharma and small biotechnology collaborations on the other.

- Industry-academic collaborations

The most typical pharma-industry agreements are:

1. Informal collaborations at scientist level. The most typical form of these collaborations is scientists co-writing papers. This finding supports the use of publication data as informal collaborations in the quantitative profiles of the sample firms. The data obtained reveals an extensive increase in informal collaborations between the sample firms and academia.
2. Material transfers, the most common example of which occurs when big pharma firms pass some of their molecules to university groups for improvement, e.g. with the purpose of testing them in a new system.

3. Sponsored research agreements, which are collaborations where a university group carries out studies on some molecules in which the firms are interested in. According to a director of Alliance Management at AstraZeneca, these have the potential to develop into much larger scale collaborations.
4. Large scale collaborations including several scientists, both at the university and the big pharma firms, e.g. GSK and Imperial College.

- Big pharma and small biotech collaborations

The most typical big pharma and small biotechnology collaborations are:

1. Arm's length licensing, which is a contractual arrangement between a big pharma firm and a small biotechnology firm, where the small biotechnology firm permits the big pharma firm to take over their drug in exchange for a royalty.
2. Option-based collaborations, which are collaborations between big pharma and small biotechnology firms, where big pharma enters into an early stage collaborative project on the small firm's products. Depending on how the product is progressing, the big pharma firm will have the option to take it further.
3. Large scale collaborations, which include several scientists at both sides of the firms working on a number of projects, often spread over the whole development cycle, e.g. AstraZeneca's collaborations with Abgenix and CAT.
4. Collaborations around the development of big pharma's own products. A representative from Alliance Management at AstraZeneca highlights that the firm increasingly collaborates on its own products with small biotechnology companies that have technologies in biomarkers, which help to assess how effective pharma's products are.

Though the findings are in two distinctive groups, it is important to remember that there is a 'grey' zone between the different types of collaborations, whereby both in-licensing and

option-based collaborations can be formed between industry and academia. However, a Head of Biopharma Partnerships at a University stressed that in-licensing agreements between her University and industry happen on very rare occasions. This is further confirmed by the Senior Manager in Drug Discovery Finance at GSK stating that although the company is in the process of engaging more formally with universities, 'option-based collaborations' are mostly formed with small biotechnology firms.

Asked about the frequencies of the different collaborations, a Senior Manager in Alliance Management at AstraZeneca expressed the view that 'sponsored research' and 'material transfers' were by far the most frequent types of collaborations that the big pharma companies engage in. Big in-licensing agreements are less common, as illustrated in the following statement: "*The less numerous ones are the larger, the types of in-licensing deals where we're paying millions to license*".

Although the above illustrates that big pharma firms actively seek to pursue their aims of: i) finding new areas or targets and ii) helping through the development of their own products by forming collaborations with both academia and small biotechnology firms, the collaborations formed with universities seem to be more research oriented, while the collaborations with biotechnology firms are more focused on 'development'. In addition to this, the fact that 'material transfers' are ranked as one of the most frequent types of collaborations means that university scientists play a crucial role in the development of the sample firms' own products.

Having classified the various types of collaborations, the key question is: what value do the different collaborations have for firms' innovation and to what extent have the various types of collaborations the potential to improve their innovative capabilities?

5.2.4 The value of the different types of collaborations

Interestingly, despite the finding that university scientists play a crucial role in the development of big pharma's products, university-big pharma collaborations have a lower perceived value for innovation than inter-firm collaborations. As illustrated in the quotes below, the key reason for this perception is that these collaborations are more 'research oriented' in nature than collaborations with small biotechnology firms (which most often focus on the development of the small biotechnology firms' products):

"The research phase is so unpredictable that you can't really measure the outcomes of the university collaborations". (Senior Manager R&D, AZ)

More evidence for this comes from an interview with a Senior Manager in Alliance Management at AstraZeneca. Asked about the importance of academic collaborations, his first response was: *"They're all for me at slightly arm-waving levels, for which I apologise"*. He then went on explaining his position, "*We have to remind ourselves how valuations happen in this industry. There are a number of sources of information: consultancies; what's happening in the market place, [which] actually tells us [a lot] if you look at the share price of any of the major pharmaceutical companies; and people who know how to do this and break that down into share price X, where is that value coming from. Most of those analysts are telling you that the market place puts negligible value on our discovery effort. Now that is not to say that our discoveries are worthless. What that says is that when the market puts the price on a public company like AstraZeneca, which it does through the share price, the share price does not factor in the value of the discovery programmes or the knowledge which is absolutely fundamental for developing the pipeline going forward. There are two major reasons why they don't do it:*

i) it is impossible to do [it] because of the way the financial valuations apply to products. [For example] you can do a discounted cash flows on a pharmaceutical

development compound, [but] by the time you're back in discovery, you're so far away from the market place in time and the attrition rate is so enormous, you can't [come up with a reliable value].

ii) *Every discovery product is negligible and it gets slightly less negligible because tomorrow it is going in development. Valuing early development programmes is difficult, valuing discovery efforts is impossible".*

Interestingly, the last sentence of the quote, i.e. *"valuing early development programmes is difficult"* suggests that early stage option-based collaborations formed with small biotechnology firms are also difficult to value. On the other hand, the value of in-licensing agreements is clearly illustrated in the following statement, *"Although in-licensing agreements are smaller in number – in terms of value and cost, basically they're much larger".*

5.2.5 Collaborations' impact on innovative capabilities

Though the fact that the different collaborations have different perceived value for big pharma's innovations, the research sought to understand their potential for building innovative capabilities. This question is reinforced in the following statement made by the CEO of AZ in Bioworld: *"Partnerships make it possible to access the skills that are needed to explore new and complex areas"* (Bioworld, 2010), as the statement is understood to emphasise the importance of collaborations for improving a firm's innovative capabilities. In addition, this was identified as a key question in the archival analysis.

The Head of Biopharma Partnerships at Imperial College, co-author of Atun *et al.* (2007), stated (when interviewed for this research) that only joint ventures, collaborative research

and in-sourcing have the potential to improve a firm's innovative capabilities. This statement laid a basis for investigating the potential of the different collaborations for building innovative capabilities with representatives ranging from scientists and Senior Managers in both R&D and Alliance Management across all the pharma firms in the sample as well as directors of two small biotechnology firms. The findings are presented below under the two types of collaboration: big pharma-small biotech collaborations and industry-academic collaborations.

- Big pharma and small biotech collaborations

In order to obtain a deep insight into the importance of inter-firm collaborations for capacity building, it was deemed important to include a variety of types of collaborations, i.e. arm's length licensing agreements, option-based- and large scale collaborations. The rationale for including in-licensing agreements and large scale collaboration was that they represent the extreme ends of the partnering spectrum (Atun, 2007) allowing contrasts in answers and, as such, giving a basis to investigate the claim[14] of the Head of Biopharma Partnerships at Imperial College. Although in-licensing agreements are least 'collaborative' form, investigating their distinctive impacts was intriguing due to direct indications that the collaborative element specifically related to in-licensing agreements has become deeper since the 1980s (see quotes below). This section seeks to present the findings related to in-licensing and option-based collaborations first, followed by the findings regarding the large-scale collaborations.

The quotes below illustrate the collaborative element found in in-licensing agreements:

[14] I.e. that only joint ventures, collaborative research and in-sourcing have the potential of improving on a firm's innovative capabilities

"There [are] very, very few licensing agreements, I would say, where it is simply a case of them buying something and then it gets thrown over the wall to the other organisation but those are very, very much the exception" (Senior Manager, Alliance Management, AZ).

"Traditionally when we say in-licensing, it still involves a significant element of technology transfer and also perhaps a significant collaborative element. You can license a molecule from company X. [However], because we want to develop it, there will still be a significant collaborative element at any stages of that. If, you know, we end up doing all the development once it reaches the clinic, they will need to discuss a degree of development and a particular plan of work, and then we need to put in place certain milestones for us to [be able to] say: yeah this technology is doing what we wanted [it] to do. So it is very much collaborative, even though it is called in-licensing" (Senior Manager, Alliance Management, AZ).

Interestingly, the investigation into in-licensing and option-based collaborations' impacts on innovative capabilities showed, despite the greater collaborative element, a great scepticism towards the potential of in-licensing agreements and early stage collaborations with regard to learning, as illustrated in the following statements.

As a direct response to the question to whether big pharma learns through collaborations, a Head of R&D (GSK) said:

"No, no, we don't learn through collaborations. That innovative thing's hard, isn't it? It's a hard word, actually"

A Senior Manager at AZ emphasised that the core motivation for these types of collaboration are products, as illustrated below:

"It is products, not learning that we're interested in when we form collaborations with biotech firms".

Asked about learning, a scientist at Pfizer, claiming to daily work in collaboration, stated:

"I have never learnt anything from collaborations; collaborations simply were a way to develop something faster than would have been possible at Pfizer, to reduce costs, simple as that!"

The only interviewee (a Senior Manager in Alliance Management at Merck) that provided some insight that an in-licensing agreement has potential for learning, emphasised that this is a 'strategic' learning, as illustrated in the quote below:

If an alliance works as it should their [the partnering firm's] work leaves an imprint on the firm and tells us if this is a route we should take".

However, although indicating the possibility of some strategic learning, the same Senior Manager seemed to suggest that learning takes place in more collaborative partnerships, as he continued:

"A good licensing agreement can lay a basis for a solid partnership".

There seemed to be a consensus in the interviews that the possibility of learning from these types of collaborations was limited, and that products are key for these collaborations, as illustrated in the following statement.

"Now is learning the key? I don't think learning is the key. Products are the key! That is what it is all about! And whatever learning you need for [developing] the products, that's obviously fully allowed. In other areas it may be different, but certainly it is all about the compounds, it all about the products"

Deeper insight into the limited possibility of learning from these types of collaborations was obtained in the interviews with a Head of R&D at GSK and a scientist at Pfizer.

The Head of R&D at GSK referred to the literature to back her general scepticism to the possibility of learning from other firms, claiming this confirmed the inability of R&D departments to learn from anything that was not invented there. Applying this to the pharmaceutical industry, the Head of R&D saw this as part of the nature of scientists; *"they have to personally validate the information"*.

The scientist from Pfizer, on the other hand, attributed the problem of big pharma firms not learning from smaller biotech firms to his idea that big pharma firms do not have enough knowledge in biotechnology to seek complementary skills. The other problem was, as he saw it, related to the fact that big pharma firms are required to learn everything about a product in a few weeks from a firm that has been immersed in the project for years, as illustrated in the following statement: *"the small company that has worked on the project for five years has all the knowledge and then the big company comes on and tries to understand things – and gets it all wrong!"*.

The same scientist also sees learning and knowledge transfer as difficult for a number of other different reasons, i.e. the fact that the small and the large firms have different mindsets, arrogance on the part of the large firms, unwillingness on the part of small firms to share their knowledge, as they often were bound to various contracts with other firms, and to the small firms' lack of formal supporting evidence and failing filing systems. The insight shared by this scientist was investigated further in interviews with other scientists, providing a deeper understanding of how the different factors negatively affect learning.

- Bad filing systems on the part of small firms. Several scientists in big pharma firms see a bad filing system as negatively affecting learning in two different ways. Firstly, a bad filing system makes the big pharma firms question the reliability of the small biotech firms' findings, which has the unfortunate effect of not only making big pharma less interested in learning from the smaller firm, but also of making the big pharma use the scarce time to look for gaps in evidence rather than to learn.

- Contracts with third parties. An interview with a scientist reveals that learning has been prevented due to the fact that the key concepts that big pharma needs to understand are parts of contracts with several third parties and, as such, the small biotech firm has been legally bound not to disclose this information.

- Arrogance and inferiority. Scientists and Senior Managers confirm that arrogance on the part of big pharma has had adverse impacts on learning. Interestingly, an arrogant attitude was shown in one of the interviews and clearly illustrates how arrogance can negatively affect firm learning. Using T-shirts as a metaphor for capabilities, the interviewee questioned why a firm that already had won 'all the T-shirts' on the market place would need to learn from external parties.

Representing 'the other side' of these types of collaborations, a Director of a biotechnology company (hired in to carry out specific work for big pharma firms) supported the general view that collaborations have limited impact on pharma's capacity building. Interestingly, although emphasising that there are high level scientists in pharma and that he sees lots of learning happening between the partners in this type of collaboration, he doubted the extent to which they could *"walk away with it"* [i.e. exploit it] given that the work mainly was carried out at his firm. *"It's very difficult to peak what we do, very difficult. We do the difficult stuff and that's why [it is so difficult]"*.

Pointing to the high level of expertise found in big pharma, the Director of a biotechnology firm ironically said that although the large firms have outsourced part of their work to them, *"it feels like the large firms have outsourced their staff to the small firms like mine"*.

To recap, part of the rationale for including in-licensing agreements and option-based collaborations into the investigation on the importance collaborations have for learning and their impact on capability building rests on indications that the collaborative element in in-licensing and option-based collaborations has increased over time. In this light, an interview with yet another Senior Manager in Alliance Management was quite interesting, as it revealed that, contrary to what was expected, it is the small firms' rather than big pharma's desire to learn that has been the driving force for this change. Importantly, in addition to providing a deeper understanding of the limited effects these types of collaborations have for big pharma, this finding stands in clear contrast to the underlying assumption of this investigation.

The first quote illustrates the importance of small firms' drive to learn:

"As times have gone on, the biotechnology industry has gone much more savvy, and many of the biotechnology companies have business aspirations and business plans to become fully integrated pharmaceutical companies. So what do they [i.e. small biotechnology firms] want to do? They not only want to share some of the risk in the crystal ball and want to share the profits involved, but [also] they want to learn how to do the things they currently can't do. That's why they're coming to us and they want to learn and they want to get involved all of the way".

The next quote not only illustrates the small firms being the driving force behind the closer interactions found between big pharma and small biotechnology firms in licensing

agreements, but illustrates big pharma's hesitation to this closer interaction, confirming yet again that it is products rather than learning that is the prime motivation for big pharma entering into collaborations with small biotech firms.

"A typical deal now does not say: 'we're selling you the crown jewel for X pounds'. It says: 'we will jointly develop the crown jewel. We will jointly do this, we will jointly do that and we will jointly do the other'. And that, if I am honest – and why shouldn't I be? – is really [what] the developing business needs in the biotechnology firms that they have driven. Well... I retract that. They haven't driven, but they have been a major driving force for the evolution of the pharmaceutical partnering participate behaviour. I don't think I am giving very much away when I say [that] if I was given a choice between a deal that says: 'I give you X pounds for the crystal ball and it is entirely up to me' or 'we'll do it jointly'; and if I'm a big player, which has got away with all of it, and you're just a player with a crystal ball, I would rather pay you money and run! [This choice would] make my life easier, simpler: I have all the control and I can make all the decisions".

Although confirming that there is little learning, the same Senior Manager from AstraZeneca revealed that *"learning is gradually coming on the map"* and is becoming one of the reasons why big pharma firms want to collaborate. Inquiring into the key criteria needed for a collaboration to have an impact on learning and capability with the same Senior Manager highlighted that the collaborations had to be of a 'certain' size and that there had to be a more pronounced strategy to enter a specific area. This finding is directly in line with the findings showing more positive perception regarding the impact large scale collaborations have on innovative capability. In summary, the general perception of the interviewees was that this type of collaboration is more 'designed' to access new knowledge and, because of the wider involvement of the firms, the learning was seen to have a bigger effect on its innovative capabilities.

In summary, in addition to the finding that large scale collaborations seem to have a greater potential to contribute to learning, the rejection of in-licensing agreements and options-based collaborations seems to confirm the initial perception of the Head of Biopharma Partnerships at Imperial College, i.e. only joint venture, collaborative research and in-sourcing have the potential to improve a firm's innovative capabilities. Putting the arguments of the various interviews together, the key reason for rejecting the potential of in-licensing agreements and option-based collaborations to build innovative capabilities seems to be that these collaborations centre around products, where most of the early stage work has taken place at the smaller firm and, as such, do not provide the scientists of big pharma with sufficient involvement to allow the scientists to immerse themselves in the knowledge and make their own validations of the data.

- Big pharma – Academic collaborations

When investigating the potential of big pharma-university collaborations for capability building, the 'discussions' were dominated by the view that there is a gap in knowledge base between the industry and academia. Inquiring into the possible implications of the gap, the emphasis of the interviewees ranged from those who regarded the gap of knowledge between industry and academia as a clear barrier to learning across the institutions, to those who emphasised that exactly because of the gap, the big pharma firms need to collaborate with universities. More insight into the various implications of this gap is given below.

The first quote, from a scientist at GSK, illustrates the extent of the gap:

"My first impression of the industry was that it is ten years behind academic research. Yeah, the people were scientifically weak, slow, and I was just thinking what on earth! It is obvious that such a gap presented a clear barrier to learning". (Scientist, GSK)

The next quote shows that the gap is so big that only by tailoring PhD projects is big pharma able to learn:

"The universities [are] too far ahead in the horizons for the companies to learn anything from them. The only real sources of learning would come from the PhD students that were funded by Pfizer as you could tailor the project, and by following it through, you would actually learn from it". (Scientist, Pfizer)

The following two quotes show that due to the gap between universities and the industry, the universities play an advisory role in important or practical questions:

"Because of a gap between academia and the industry, academia serves an important role, advising and guiding big pharma in more important questions". (Senior Manager, Alliance Management, Merck)

"A key strategy to obtain complementary skills is to collaborate with academics. Academics are higher up in the horizons than us. We contact them either because there is something we cannot do internally, or we need some sort of advice". (Senior Manager, Alliance Management, AZ)

The last quote not only provides a deeper insight into the extent of the gap but also illustrates the importance of collaborating with academics in order to get an understanding of the development of the fundamental knowledge which will lay a basis for future drugs:

"*It is crucial to partner with Professor X because of his insights and his knowledge and [because], right at the beginnings of our pipeline, the drugs that AstraZeneca will launch in the second half of the 21st century – that's scary: 40 years away – [have] the fundamental biology on which they are going to be built being researched in academia*

today and tomorrow. That's how long it takes so their fundamental biology is absolutely pivotal". (Senior Manager, Alliance Management, AZ).

Interestingly, however, when inquiring into the potential of industry-academic collaborations for improving a big pharma firm's innovative capabilities with the Head of Biopharma Partnerships at a University, a gap of knowledge was not mentioned. Instead, she focused on the criteria which allow learning to occur in this type of collaboration. In addition to seeing that certain types of collaborations, i.e. joint ventures, collaborative research and in-sourcing, have the potential of improving on a firm's innovative capabilities, the Head also sees it crucially important to have 'champions' on both sides of the collaborations as well as creating the 'right' environment for stimulating knowledge transfer. Of more institutional factors, the Head sees it as important to secure some sort of endorsement from the higher levels of the firm, but also emphasised the importance of her University encouraging commercial interests.

In summary, the fact that the interviewees highlighted the importance of large scale collaborations not only seems to be directly in line with the Head of Biopharma Partnerships' initial statement, that only joint ventures have an impact, but also provides an important criterion for collaborative research to have an impact on learning. As seen above, the main reasons for bigger potential of larger scale collaborations are: i) a more explicit aim of acquiring new knowledge and ii) a deeper involvement throughout the firm. Given the large resources involved in large scale collaborations, these types of collaborations are also likely to be endorsed by Senior Management, which was a criterion indicated by the Head of Biopharma Partnerships herself.

Whilst rejecting in-licensing and option-based collaborations seems in itself to be in line with the Head of Biopharma Partnerships initial statement, the reasoning underlying this

rejection provides a deeper understanding of the criteria needed for *collaborative research* to positively impact the innovative performance of a firm. Specifically, the above findings suggest that for a collaboration to have an impact on the innovative capabilities of a firm, the 'student' firm (to use the same term as in Lane and Lubatkin, 1998) must be involved in the early stages of work to build up a knowledge base which then enables the scientists to validate the data. The knowledge acquisition seems to be dependent on a range of things, i.e. knowledge overlap between the partnering firms, willingness to share knowledge and learn and an efficient filing system. The Head of Biopharma Partnerships' own criterion, for collaborations to have champions, seems to provide additional insight into how partnerships can positively affect inter-organisational learning.

5.2.6 When do firms seek to carry out acquisitions in preference to forming collaborations?

Comparing the use of collaborations with a more formalised strategy, such as acquisitions, was thought to provide a deeper understanding of collaborations.

When inquiring into the rationale for carrying out acquisitions over entering into collaboration, the general perception was that acquisitions, to a larger degree than collaborations, are used to obtain a more 'definite' position in a specific area. This perception was in direct line with the underlying argument above that 'carrying out acquisitions' is a more formalised strategy than collaboration. Interestingly, consequent to their claim that acquisitions are used to enter into new areas, the interviewees also regarded this strategy's potential for building innovative capabilities as greater than that of collaborations, though recognising that carrying out acquisitions is a riskier strategy than forming collaborations. The following quotes illustrate the importance of acquisitions for building innovative capabilities:

"I think if they're acquiring competences you can develop your core competences" (Scientist, GSK)

"From a firm's point of view, the best strategy for learning something new, though risky should the project fall over, would be to acquire a company. In this way, the new firms would feed directly into the relevant TA [i.e. therapeutic area]" (Scientist, Pfizer)

The view that acquisitions are more suitable to enter into new areas is supported by the fact that single acquisitions of biotechnology firms was one of the key strategies for the sample firms entering into biologics supports (see section 5.2.2). Interestingly, however, it was contradicted by a pharma consultant, who sees the increasing reliance on acquisitions of small biotechnology firms as a mere strategy of big pharma firms to obtain new products, as illustrated in the following quote: *"If you look at all the acquisitions that big pharmaceutical firms have carried out over the years, you would see that they [the small firms] have a promising product in phase 3 [of the drug development]. It is the drugs not their knowledge they're after".*

Given the contrasting evidence regarding the importance played by acquisitions for capability building, it was regarded as important to investigate the actual impacts of the acquired firms in this regard. The investigation revealed that only a few of the acquired firms had had an impact on big pharma's capability building. Specifically, an interview with a Senior Manager in R&D at AstraZeneca revealed most of the single acquisitions that AstraZeneca has carried out over the years are narrowly applied and, hence, have a limited impact on the innovative capabilities. Similarly, a Senior Manager in Alliance Management at Merck, revealed that only in a few cases was the perceived value of the acquired firms' knowledge so high that Merck had actively sought to assimilate and learnt from it. However, when enquiring into the specific measures that Merck had used to

assimilate this knowledge, it appeared that Merck only set up meetings rather than using more explicit measures, i.e. 'internal collaborations' or job share between the departments.

Despite contrasting evidence regarding the effects of acquisitions on capability building, the strategy seems to be of key importance in the future. More specifically, an in-depth interview with a Senior Manager in Alliance Management at AZ revealed that one of the most pronounced risks in collaborating with a smaller biotechnology firm is that this firm will be acquired by a third party, as illustrated in the following statement: *"There is a risk in partnering and that is not the risk that the project might fail or that the relationship might break down. Those risks we have to live with. The other risk we have to live with is that our partner is acquired by a third party"*. Expanding on this, the director highlights the continuously growing importance of acquisitions, citing the difficulty of collaborating as a key reason for this, as illustrated in the following quote: *"Strategically, you know, I don't think you have to be a global speculator type of person to anticipate the possibility that, in 50 years down the road, acquisition will be an aggressive tactic to take out competitors. You know, partnering is difficult."*

5.2.7 Why has R&D failed to deliver?

The most typical response when inquiring into the reasons for the R&D inefficiency with representatives from the selected big pharma firms was: *"all the easy things have already been done and not least, a much stricter regulatory environment"*. This response is directly in line with the arguments used to explain their increasing reliance on collaborations, i.e. *'traditional knowledge base has been pretty harvested'* as well as *'a stricter regulatory environment'* (see section 5.2.1)

A Head of R&D at GSK pointed further to the disadvantages of being a large firm: *"there is an argument that when you are big you can't find those compounds because you're so busy playing with the finances, the bureaucracy and blah, blah"*.

A scientist at Pfizer provides a deeper insight into how the disadvantages associated with large firms negatively affect innovation. Key to his argument is that bureaucracy inhibits the incentives for scientists to be innovative, as illustrated in the quotes below:

"I mean it has to go to three levels of management for approval before doing anything. If we want a piece of equipment for instance, it takes six weeks to order it, even if the shop's next door, and then wait six weeks for health and safety to test and approve it and then it has to go through I don't know what, and then people have to be trained on it, and that's three months for something that should take three hours to do. I think just the efficiency of big companies is zero. Whilst if I were working at a small company I would just go to the shop and get the equipment, and then I would have to install it myself. With a bureaucracy like this, there are no incentives to be innovative".

"The bureaucracy creates a mind set of doing things nice and slow, nice and slow and that's why people don't move fast".

"If I now were to develop an idea and go to the company, they would say OK thank you very much and that would be it. There would be no financial reward, there would be no... there might be a recognition in the sense that you might get a certificate or a name on an email but other than that. For me, there're just no incentives for us. Personally if I had an idea, I would rather develop the skills and then start up a company. A good molecule is worth a billion dollars, so if you can start up yourself, the billion dollars is yours. Whereas

if I go to the company and say I have created this molecule, I don't get a billion dollars, I might get a £10 gift voucher".

A former Professor in Health Management, on the other hand, does not hold size as the issue but rather the system, pointing at big pharma's monolithic structures and the fact that they: *"employ too similar people, do not engage in open innovation and are risk averse".*

These factors might be the underlying reasons for big pharma largely ignoring biotechnology until the beginning of the 1990s, which a pharma consultant sees as a key reason for the R&D inefficiency. Ironically, as this consultant sees it, it was the denials of big pharma firms throughout the 1980s that actually allowed the biotech revolution to happen. Directly in line with Schuker and Williams (2007) (see chapter one), the consultant confirms that the real turning point came in 1993 when SmithKline Beecham signed a landmark agreement with Human Genome Sciences. According to the pharma consultant, although other companies had formed partnerships with biotech companies prior to 1993, i.e. Eli Lilly formed a partnership with Genentech and J&J with Amgen, it was this single event that really 'opened the eyes' of big pharma, and made them start to embrace the new biotechnology methods. It was, according to the consultant, at this very point that big pharma really started to invest in the new technology

The finding that big pharma firms are latecomers in biotechnology is coherent with a Professor in Molecular Neurology and Founder of a biotechnology firm, whose first reaction to the question of why innovation has faltered was that big pharma firms *"lag badly behind in technology".*

Of similar importance, the Professor further highlighted that *"they have asked the wrong questions".* In terms of the latter, the Professor stressed that in his opinion they were

asking the wrong questions as to where certain targets are, which is often decided on the basis *"that everybody else is looking at them"*, a finding that was supported by a pharmaceutical consultant. In addition, he attributed the problem of asking the wrong questions to the fact that the major strategy of big firms has been looking at gene changes, as illustrated in the following statement:

"They went micro range, [...] so look at gene changes, [...] all that stuff. They wanted to hit the pure target, so for example we know that sodium channels regulate pain, I know that it sits in the sodium channels,[...]. Well, you're almost doomed from the kick off moment, purely speaking as an academic, because the first thing you need to know is where is that target, [...] is it just in the sodium channels or is it in the heart?".

Instead of gene changes, the Professor in Molecular Neurology claimed, *"you need a whole organisms physiologist, somebody that understands the whole body, you know, not [someone who] only tells you what happens in the gene. You need physiologists, [as] they will know what to do with the [molecule], [i.e.] know what's doable, predict that we will have problems with this, [that we should not] do that. Only by employing physiologists are you able to make really predictive models"*. The Professor went further, saying: *"ultimately you will need the mathematicians, you will need the modellers, and people are investing in [them] but it's going to take a few years before it comes to the front".*

According to the Professor, asking the wrong questions does not only affect big pharma's ability to identify the targets for new treatments, but also to identify the most promising existing compounds. The latter is illustrated in the quote below:

"I absolutely believe that they almost certainly have a whole pile of very effective treatments that are sitting on their shelves [but] they just don't know how to fish them out and actually make the most of them, and turn them into real therapeutic benefits".

In addition to failing to ask the right questions, the Professor in Molecular Neurology emphasised that building capabilities takes time and holds that the system does not allow you this time, as illustrated in the following statements: *"They're shareholder economy driven, and that kills you. You don't fix neurological problems in five years, but the shareholders are going to be paid off in that time. Frankly, to me, the whole model stinks: it's all geared up to failure. If you want to commit to something, I think you need a bare minimum of a 10 year commitment, not this two or three years [approach], or [the approach where if] one of our compound's not doing so well, we've got to lay everybody off".*

By not allowing the scientists enough time and the fact that *"decisions are not driven from a science or long term future base on how to go further, they're purely financially driven"*, the Professor believes that *"the system has kicked its own scientists in the teeth"*. As a last point, the Professor addressed a concern that, at a time when the big pharma companies more than ever need to cut their costs, "*the middle management needs to go, and that's where your talent is*".

Overall, the Professor said: *"you see them fail because they're blinkered, tunnel-visioned and the way pharma is actually set up is actually geared to failure, in my honest opinion, totally geared to failure. In addition to this, the way they've gone merger, merger, merger, they're now just giants, completely inept. And so I think they'll continue to fail".*

In summary, representatives from big pharma primarily argue that R&D has failed because of the disadvantages of being a large firm, with particular reference to bureaucracy. Interviewees from outside big pharma on the other hand explain the R&D inefficiency with big pharma employing too similar people, being risk averse.

5.2.8 Changing role of R&D

Importantly, the increasing reliance on collaborations over time, illustrated in the quantitative profiles, seems to have clear implications for the role of the selected firms' R&D.

The first person to approach this was a Head of R&D (GSK). Although the importance of collaborations was highlighted in the interviews the researcher carried out prior to this interview, it was in this interview that the key finding was first reached, i.e. that the role of big pharma's R&D had changed as a result of the increasing reliance on collaborations, and as such the key ability was to recognise useful knowledge of potential collaborators, which is an essential component of absorptive capacity. This is illustrated in the following extract, where 'I' stands for 'Interviewee' whilst 'R' stands for 'Researcher':

R: *How important would you say collaborations are for GSK's economic performance?*

I: *[....] Typically, if you look at any large pharma company, a large proportion of the things they finally get on the market has not come from their research labs, they've come from small companies. And we have a number of different models to work in with that [...].*

R: *So what importance do you really place on R&D and collaborations in terms of their distinctive contributions to the economic performance?*

I: *In my personal opinion, I think that big pharma is really about development. So, I think, it's about the machine.*

R: *the machine?* [15]

I: *Obviously we can't do anything without compounds. And there is an argument that if you're big, you can't find those compounds because you're so busy playing with the finances, the bureaucracy etc. But, even so, I think [that] if you look at the track record of most pharma companies, the most important thing is the ability to recognise a good compound and then do a very good development job on it. Go for the right clinical trials, go for the right indications, go for the right labels. So, I would go for [collaborations]"*

(Extract 1)

Summarising her views metaphorically, this Head of R&D said: *"I think the most important thing for us is making sure we back the right horse and that we put [it] in the right races and we have made sure it is not being doped on the way, you know, as a company"* (Quote 1)

The fact that a head of R&D emphasised the ability to recognise an externally developed compound as a key capability over the ability to generate the compounds in-house (Quote 1) was not only surprising but gave the research a new dimension. The subsequent interviews with various representatives of big pharma companies as well as academics sought to investigate this new dimension further by enquiring into the key roles of R&D (i.e. Quotes: 2-5) as well as to what extent to which this represents a change of roles in R&D (i.e. Quotes 6-9). Below are some of the answers obtained.

Enquiring about the key role of R&D of big pharma firms with a Professor in Health Management and Scientist at Pfizer, both highlighted the key role of development (Quotes

[15] Though the interviewee does not explain the word machine, the expression has been used by others and refers to big pharma's engagement in the development of a vast number of products.

2 and 3). The scientist provided, however, more insight into the specific roles underlying 'development' (Quote 3).

"The big pharma companies are just development companies, taking over the drug after phase 2" (Quote 2)

"I think R&D is just product development. I think that [this] is how it works in R&D. Whether that is a research party [i.e. a research team] understanding and characterising [externally developed] molecules or devices, [still there is] the risk of the development program; research is complementary to development in pharmaceutical. To me, research alone does not get you anywhere". (Quote 3). The scientist, continued, saying: *"I think the idea is to get these business development and licensing teams to have quite a wide range of people so when you go on to do due diligence, which means that you seek to value a technology that has been produced in another company, you need a wide range of people for that. For instance, you need a few toxicologists to understand if a drug is safe".* (Quote 4)

Inquiring further into the key role of R&D with another scientist at GSK highlighted the last point of the scientist from Pfizer (Quote 4), saying: *"The findings of small firms aren't always robust – you need to be able to evaluate them".* (Quote 5)

A former Head of IT at GSK highlighted the change in the role of R&D over time, by reflecting on his own experience working in the labs twenty years ago and comparing it with how R&D is carried out today. The Head clearly attributed the change in the role of R&D to increasing reliance on collaborations, stating: *"The role of R&D has changed, obviously because managing the relationships [collaborations] now is enormously*

important, so in that respect it has changed. Other things have remained the same". (Quote 6)

Although this person hinted that a reliance on collaborations is particularly evident in a particular phase of the life cycle that the firm is in, pointing to the critical situation Glaxo was in prior to the GSK merger, a Senior Manager in Finance at GSK emphasised the increasing importance on collaborations, saying: *"The increased reliance on collaboration in our business is a fundamental change. The question is more on what level we will reach in the future, so the ability to identify external knowledge is a core capability"* (Quote 7)

Asked to what extent the role of big pharma's R&D has changed over time, a Senior Manager at AZ stated that due to the increasing importance of biotechnology firms, big pharma firms have become increasingly concerned with identifying externally developed compounds and, as such, this interview directly confirms the statement held by the Head of R&D at GSK (i.e. Extract 1).

"I think historically it was considered that pharma knew exactly, it knew its business, how to develop drugs, it didn't really need a lot of support in many ways. I think there has been a certain critical change in the mindset where pharma realises that biotechnology firms are actually often better in specific areas so I think, you know, in-house R&D has developed with that in mind, where it realises that it doesn't own or have all the knowledge or the pieces of the puzzle and therefore has to access that from external sources so, in-house R&D is becoming better at integrating, I should say identifying, valuing and integrating external expertise, data and compounds, so it had to change considerably" (Quote 8).

Asked explicitly about the consequences the growing reliance on collaborations have had on R&D, a Senior Manager in R&D at AstraZeneca's response was: *"I think the underlying theme that you've identified that, you know, let me caricature it for you: A monolithic, global, major pharmaceutical company exclusively relying on sort of myopic, blinkered view of its own internal research skills at [one] end of the spectrum, and the other end of the spectrum is a completely de-structured R&D activity, which are just a developer and a manufacturer and a marketer of other people's drugs and you know, we are, there are cracks appearing in the monolithic pharma R&D structure, because it is actually proving not to be as efficient and effective and, if you like, economic enough in its invention of new drugs and it is forced to change, and that change process I believe will continue but it's started; the major pharma companies are experimenting slightly different structure in the ways of doing it but nonetheless, I don't think the restructuring process has finished yet and we will be investing, I believe, in the next few years more externally as a proportion of that total R&D investment than we are today. Now at the moment, you know, the activities searching outside for how they work is much better than they were three to four years ago. However, the community of R&D staff not all of them are not as outward looking and as competitive that maybe they need to be because culturally they come from a different place so yes, it is changing R&D, yes the proportion of what we get outside, I believe, will be going up and the attitude of the younger research staff will be sort of [more] core activities in the future. We would want to encourage them to be more outward looking than the ones that we have today, because, you know, there are some shocking facts out there, one that always gets quoted, that the productivity per dollar has fallen steadily since the 1960s, and the patents per dollar is dropping, and the number of drugs that finally get through regulatory agencies is dropping year on year etc, etc, perhaps with the exception of biologics, although that is down to change, I think. And therefore that a model for what's sustainable, so you're forced to change".* (Quote 9)

Asking key interviewees about the key roles of R&D, and to what extent there has been a change in these roles, has given further evidence for, as well as enriched, the key points of Extract 1. In other words, whilst Quotes 2 and 3 share the view of the Head of R&D, that the main role of big pharma is 'development' (Extract 1), by holding that the role of R&D has changed in relation to collaborations becoming increasingly important, Quote 6 seems to indicate that 'development' becoming the main activity of big pharma is caused by the sector's increasing reliance on collaboration. Finally, it is in the context of emphasising the continued importance of collaborations that Quote 8 highlights the key role of identifying external knowledge as a core capability and, as such, confirms the key message in Extract 1, i.e. *the most important thing is the ability to recognise a good compound and then do a very good development job on it.*

The argument above confirms that, as collaborations have become increasingly important, the main activity of big pharma now centres around development, thus confirming previous findings holding that there has been a 'division of labour' between small and large firms (Gambardella, 1995). This might also add to the finding holding that in order to profit from its main activity (i.e. development), big pharma's key ability lies in recognising new relevant knowledge.

Interestingly, the fact that there is a clear link between the key roles of R&D presented in the quotes and the definition of absorptive capacity provides evidence that it is absorptive capacity that the various interviewees refer to. This point is illustrated by comparing the various key abilities of R&D presented in the various quotes, i.e. 'recognise' (Extract 1), 'understand', 'characterise' and 'assess' externally developed molecules and drugs, as well as the risk attached to a development program (Quotes: 3 and 5), with the absorptive capacity literature. This proves that although it is only 'identification' that literally

corresponds to one of the dimensions of absorptive capacity[16] (Zahra and George, 2002), the other abilities, 'understanding', 'characterising' and 'evaluating', seem crucial for the "ability of valuing external knowledge", which corresponds to Cohen and Levinthal's (1989) own definition of absorptive capacity.

5.2.9 Dynamic relationship between R&D and collaborations

The fact that the key capability of R&D is increasingly to recognise potential collaborators gives a first indication for an inter-dependent relationship between R&D and collaborations. As seen above, the fact that the roles of R&D match the abilities of absorptive capacity provides evidence that it is absorptive capacity that mediates this relationship.

In addition to providing evidence for this relationship, the fact that this section shows that only by engaging in research is the firm able to identify suitable compounds provides direct evidence for the underlying idea of Cohen and Levinthal (1989, 1990). In fact, the importance of investing in R&D for the ability to identify the most suitable collaborators is emphasised by the fact that the interviewees see great dangers in R&D becoming a pure development and commercialisation activity. Interestingly, the fact that one of the quotes below, highlighting that investing in R&D makes it possible to draw a boundary around their capabilities, suggests that this is yet another necessity for being able to identify and exploit collaborators' knowledge.

"For me it's always what pharma thinks it wants to be. Obviously it hopes that it will produce molecules that nobody else can produce and I certainly feel that if we didn't do what we do we wouldn't understand what is going on. If we became a pure development

[16] The other are: 'assimilation', 'transformation', 'exploitation'

and commercialisation activity, I think we would have trouble because we wouldn't be able to find the right entities, to know what's out there, and you certainly wouldn't know what to have developed". (Head of R&D, GSK)

"I do subscribe to the view that innovation comes from combining ideas in different ways, so you have to have a body of knowledge that allows you to combine information and ideas in different ways, so I think that a good industrial research group needs to know about its subject, but if they don't do anything on their own, if they only are evaluating other people's ideas, they probably won't be well placed taking them forward". (Head of Biopharma Partnering)

"If we hadn't done what we do, we would never be able to assess the compounds developed by our collaborators". (Senior Manager in Alliance Management, Merck)

"It is incredibly important to have realistic judgement of the quality in a collaborative activity, and I think that judgement only comes by doing R&D. I don't think you can do it terribly well if do you it theoretically, if you know what I mean". (Senior Manager in R&D, AZ)

"The other thing is, unless you have the internal expertise, how can you value what you're bringing in". (Senior Manager in R&D, AZ)

"Investing in R&D is crucial as [...] developing our own core capabilities [...] helps us to distinguish ourselves from the smaller biotechnology companies". (Senior Manager at Drug Discovery Finance, GSK)

"[...] clearly one of the major sources of value... In-house research is a real opportunity to value the opportunity which takes place externally, to value it, you need to... it is like muscles, unless you continually work to build the muscle or at least keep the muscle toned, you're going to lose it so I think it will still, certainly for the next 20 years, in most big pharmas, they will maintain a level of in-house research, as will be seen as comparable to accessing externally. Now, I think there is still a way to go before pharma decides to easily curb all its research activities, I don't see that happening certainly in the next 10-20 years". (Senior Manager, AZ)

In summary, although investing in R&D does not seem to be the key strategy for generating new successful compounds (a view supported in the quantitative analysis), it still seems to be of crucial importance for building absorptive capacity, and hence for recognising and evaluating collaborators' knowledge.

5.3 Key processes enabling a firm to acquire, assimilate, transform and exploit knowledge

Research question two inquires into the key processes that enable firms to acquire, assimilate, transform and exploit knowledge from collaborators. As seen in chapter three, although this research question is primarily investigated through a case study, the cross-case interviews were used to obtain 'a first insight'. As seen in chapter two, the research question builds directly on a framework by Zahra and George (2002), suggesting that absorptive capacity consists of the following capabilities: acquisition, assimilation, transformation and exploitation, and that each of these capabilities are governed by distinctive processes. It is important to remember that although the research question is framed on a collaboration, the research seeks to identify the processes by which big

pharma acquires knowledge from a collaborator, and then subsequently the processes by which it assimilates, transforms and exploits this new knowledge.

Although the investigation initially built on Zahra and George's (2002) framework, the fact that the key role of R&D has become to identify and evaluate collaborators and their compounds, the research also sought to investigate the key processes enabling these capabilities. Although the focus of the investigation became larger than initially planned by including the abilities of identification and valuation, these abilities seem to be in direct line with Cohen and Levinthal's 1990 definition of absorptive capacity, i.e. the "ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (p. 2). The different capabilities, i.e. identification/evaluation of collaborators, acquisition, assimilation, transformation and exploitation of knowledge, will be presented in separate sections below.

5.3.1 Identification and evaluation of potential collaborators

As seen above, an investigation into identification and evaluation was initiated due to the finding that the role of R&D is increasingly focussed on the identification and evaluation of collaborators. In this context it is important to note that, although the focus is on how R&D identifies and evaluates new collaborators, the fact that, since the 1980s, big pharma has had specialised departments to manage the process of identifying and evaluating external partners, i.e. Alliance Management departments, meant that it was deemed crucial to start the investigation into the processes that enable identification and evaluation with Senior Managers in the Alliance Management departments across the selected firms. The distinctive abilities are presented separately below.

- Identification

Inquiring into the key processes underlying the Alliance Management departments' ability to identify suitable partners, the interviews revealed two separate avenues.

The first avenue is to *'put themselves forward as a preferred partnering firm'*. As this avenue involves marketing, it is interesting to note that all the selected firms' alliance offices have produced brochures and created their own links on the firms' websites to provide in-depth information about the areas they are interested in collaborating in (see extract below) and the firms' overall collaboration 'ethics' and values, to attract potential collaborators to apply for partnering opportunities with them.

The second avenue is to make direct contact with potential collaborators. This avenue involves screening the potential collaborators and the interviews revealed several methods by which this could be done: going through the press and academic journals, seeking direct input from the Marketing department, given their extensive market intelligence (which was further confirmed in an in-depth interview with a Senior Manager in Marketing at Pfizer), using scouts and attending biopharma partnering conferences. Despite the various ways to screen possible collaborators, it is interesting to note that all the interviewees regarded biopartnering conferences as the most effective method, as illustrated in the following quote: *"All those seeking partnering opportunities are at these conferences, it is crucial to be there"*. However, the conferences were regarded as competitive and, as such, several interviewees highlighted the importance of the managers' having obtained their own extensive network to identify the best deals, as illustrated in the quote below:

"There is a hell of a lot of competition in this area, so they would physically go out and compete in that market place and start the deal, and then they would have to escort it in-house". (Head of R&D, GSK)

"This is a very competitive arena; it is therefore essential that you build your own network to snatch the best partnering opportunities". (Senior Manager, Alliance Management, Merck)

Interestingly, and in full congruence with the key finding that the key role of R&D is to identify collaborators, interviews with several Alliance Managers revealed that despite working actively to try to contact and attract potential collaborators: *"it is through the scientists that most things come in"* (Senior Manager, AZ). The fact that the view that it is scientists that lead the game comes from the very people hired to identify collaborators arguably gives more credibility to this finding. The following extract and quotes from interviews with Alliance Managers across the firms illustrate the importance attached to the scientists.

R: *How do you go about identifying suitable collaborators?*

I: *We do brochures of what we're roughly interested in, we go to these bio-partnering conferences, we meet people there, form networks in what we're interested in. All of our scientists are part of a scientific body and [are] making contacts there. So it happens two ways, what we're interested in and they come back to us with what they've got, but equally well for specific things we go out and seek opportunities, so it's a broad arena.*

R: *You talked about scientists, how important are they and their network?*

I: *The most important thing, they're absolutely key in all of this, they have their scientific contacts with the outside world and yeah, that's actually how most things come in. That's very important.*

R: *So you mean their own personal network, e.g. friends from university and people they meet at conferences etc?*

I: *If they have contacts at a university and bringing that idea in, that's far more likely to lead to some sort of arrangement than someone who speaks with David Brennan [i.e. CEO of AZ] and passing it in".* (Senior Manager, Alliance Management, AZ)

"I think a lot of that is done through scientists to go out to external meetings, they meet people, they identify particular individuals that they are associated with, a professor in oncology, cancer or a team leader at a particular cancer centre in the US, who's doing work which is very relevant to our sort of development pathways, discovery and development pathways. So a lot of it is done through the knowledge of the scientists, they approach individuals and set up discussions from there, and at the same time a lot of people approach us. It happens in a number of different ways". (Senior Manager, Alliance Management, AZ)

"The scientists and ourselves are out and about and it is the way you come across things. Informal networks are essential". (Senior Manager, Alliance Management, Merck)

Interestingly, whilst the finding obtained by merely investigating the importance of the different strategies showed that the ability to identify collaborators depends merely on investing in R&D, this finding adds to it, showing that identification of collaborators happens through scientists' own networks, i.e. simply by being connected to a wider scientific group the scientists are able to identify collaborators.

- Evaluation

When inquiring into the key processes for *'evaluating'* potential collaborators and their knowledge, all the interviews revealed that the key for evaluating is basic knowledge in the field. Though all the senior managers emphasised that their own scientific background is sufficient for a 'first valuation of the collaborator's knowledge', they all stressed the

importance of relevant scientists making an informed evaluation of it, as illustrated in the following quote:

"We will coordinate the evaluation of the information we get from our external partners, so we'll make sure all the functions within AZ [...] review their information, and make a judgement on it. Scientists are obviously key in this process".

Given the finding that big pharma actively seeks to enter into new areas (see section 5.2.2), it was deemed important to inquire into the extent to which big pharma firms are able to value new and complex areas outside their own expertise. Interestingly, whilst an interview with a Senior Manager in Alliance Management emphasised the richness of the knowledge residing within big pharma firms in comparison to small firms, which to a larger degree would need to use external consultants, another interview with a Senior Manager emphasised the importance of using their scientists' own networks to obtain a justified judgement of the external knowledge. The fact that scientists use their own networks actively when evaluating new knowledge places even greater importance on the scientists' connectedness to a wider scientific environment.

"Basically, the folks we have, they are bright, bright people so knowledge is not only limited to areas they work on, they value and make judgement in areas they're not working on themselves and they supplement that as well by their external contacts, that's the other thing, so that for a small company, internal research, they would then entirely rely on external consultants, advisory boards, to make the judgements for them. We would also use external consultants and advisory boards but it would be to supplement our own thinking, and ask specific questions, not the entire way you would judge in a new area".

The interviews further revealed the key importance of carrying out a due diligence on the potential partnering firms for assessing the potential of a new collaborator. Given the importance attributed to such pre-deal assessments, the research sought to understand on what criteria the assessments are based. From discussion with senior managers in Alliance Management of the key criteria for selecting a partner, the 'scientific expertise of the partner' stood out as the most important criterion, as illustrated in the quotes below. The second quote, however, provides a ranking of criteria and thus gives more insight into the top criteria for selecting a partner.

"I think by miles it is the scientific expertise of the partner". (Senior Manager, AZ)

"It is my global perception of the disease and that's absolutely crucial. Who are the people, the experts, the biologists and so on who are working in that area? That is crucial, that's my number one – my ability to descend the absolute capacity position – that's absolutely crucial in terms of a collaboration. Second to that but very, very close to it, you know, does it match with, I've made this point before. does it match with the skills I've got, the capabilities and needs I've got internally? Is this something that doesn't fit at all? The third thing and I think again it is very close, and that's the culture thing. If I go there and I talked to them, is there chemistry? Is it likely to work? Can I build trust? Can I build a sense of joint-ness? Because only in that way can I build a really competitive activity and really utilise that collaboration. It worked exceptionally well with CAT; we knew very quickly that we were culturally attuned to each other". (Senior Manager, R&D, AZ)

The next quote not only illustrates the importance of the scientific expertise of the partner but emphasises the importance of the partners bringing together complementary skills to create mutual value for the firms involved.

"Clearly some of the partnerships that have been made in heaven are the ones [where] you identify two critical things: one is a piece of knowledge or a piece of capability that you really don't have that is world leading, and one in which potentially your collaborators see in you the other skills that made us have excellence in toxicology or the global reach into China if the drug is very useful in Asia or something, so you bring something to the party. And both parties believe that a collaboration is going to bring some mutual value and those are the ones that really work. Ones where people just want to have money or ones that one exploits the other don't work at all well, so the cultural aspects is in extremely good collaborations".

5.3.2 Acquisition of knowledge

Inquiring into the key processes that enable a firm to acquire knowledge from a collaborator through the cross case interviews was to some extent challenging, given the fact that so many interviewees were sceptical toward the idea that collaborations can lead to learning (see section 5.2.5). In order to encourage the interviewees, who appeared particularly sceptical regarding the potential of collaborations to build innovative capabilities, to answer, more hypothetical questions were used, i.e. what would a successful acquisition of knowledge require?

Interestingly, whilst the overall findings seemed to be directly in line with prior findings that only large scale collaborations and the specific criteria used to assess collaborators (i.e. criteria for due diligence) illustrated in the following quotes, e.g.: *"it must be part of the strategy to move into a specific area"*, *"you need a sheer number of scientists"*, *"you need to collaborate with a very good firm, arguably the best in the world"*, a few interviews with scientists across the firms provided a deeper understanding of how

complementary skills and a matching culture for knowledge acquisition affects knowledge acquisition. Their answers are presented in separate sections below.

- Complementary skills

An interview with a scientist at AZ emphasised that if a firm aims at acquiring knowledge from a collaborator, it needs to have some knowledge of the field in which the collaborator firm operates. Interestingly, whilst a successful collaborator's complementary skill could be toxicology or a global reach into China, this shows that there needs to be a knowledge overlap in the same field as the 'teacher' firm.

- Culture

Interestingly, whilst 'matching culture' was seen as a criterion to form a collaboration with another partner, scientists highlighted that in order for a firm to acquire knowledge, there must be a supporting culture that allows the transfer of knowledge. An interview with a scientist at GSK highlighted in this context, the importance of both partners being flexible with their knowledge: *"You need to be much more flexible with your knowledge when you collaborate" (Scientist, R&D, GSK).* Of more prosaic measures, the Head of Biopharma Partnerships at a University stressed the importance of arranging informal meeting at the beginning of the collaborations to stimulate the flow of ideas. Although this was not emphasised in the interviews with the scientists, a scientist from AZ stated that whilst frequent meetings are important to ensure efficient running of projects, *"it is through the face-to-face meetings with both firms when you learn"*. In addition to face-to-face meetings, both scientists and a Senior Manager in R&D highlighted the importance of setting up databases.

5.3.3 Assimilation of knowledge

Seeking to investigate the key processes that enable a firm to assimilate newly acquired knowledge across departments, the investigation intriguingly showed that, rather than formal processes, knowledge assimilation primarily happens on an informal basis.

The first quotes, made by scientists, illustrate this directly by rejecting the idea that there are any methods that allow the assimilation of knowledge but also to the extent that there are no requirements for this; the latter quote illustrating that knowledge assimilation happens informally, either through departmental meetings or between colleagues.

"I don't think there's any method for spreading what you've learnt". (Scientist, Pfizer)

"There are no formal requirements for assimilating knowledge, neither throughout the department nor across departments. This is obviously a shame as useful knowledge, in this way, easily gets lost. Should I decide to share what I have learnt, this would [be] informally at departmental meetings or perhaps more likely just with my closest colleagues. Anyway, the idea would just be to fill them in. It is not like anybody would jump up actively seeking to exploit it". (Scientist, GSK).

Inquiring explicitly into the importance of formal methods for the assimilation of new knowledge with a Head of R&D (GSK) and Senior Manager in Strategy (Pfizer), both highlighted that although there are measures that could be used for this purpose, these more formal methods are not frequently used. The Senior Manager in Strategy gave a direct example of this, stating that although Pfizer had sought to promote an innovative method for assimilating knowledge by creating a market place, where each department formed a 'stall' to 'sell' new relevant knowledge to other departments, this initiative,

though successful, was later seen to have taken up too many resources to be sustainable, as illustrated in the quote below:

"We've tried to make stalls represented by the various departments to 'sell' knowledge. This was hugely successful and we've learnt a lot. However, this took a lot of resources and we've only managed to do this once or twice".

The Head of R&D, on the other hand, pointed in a similar way to the scientist (from GSK) above, that knowledge assimilation primarily happens in informal communities, formed on the basis of interests. Interestingly, however, whilst the scientist sees it as a weakness that GSK does not have any requirements for assimilating new knowledge, the Head of R&D sees it as *"a weakness that GSK does not join up the more informal and formal communities"*. Recognising the value of the employees' knowledge, she added: *"I feel that we underestimate the institutional knowledge embedded in people".*

Inquiring further into how scientists trace necessary knowledge in their daily work in order to form a better view of how knowledge assimilation happens, the Head interestingly emphasised 'word of mouth' rather than IT solutions to trace people, emphasising that one of the core competences in such a large firm is finding one's way through it.

"There are organisational charts across the organisation so you can actually see everybody on the intranet, you can at least find out where they sit in the organisation and track them through that, I think. And actually, word of mouth is quite impressive actually because I think one of the core competences in an organisation is finding your way through it. It's hard to find everybody but usually you will eventually find a person that knows most of the things you want to find out. You'd be surprised how important word of mouth is". The Head of R&D then added: *"I certainly couldn't manage within an*

organisation this size without having that network that would allow me to function in it".

Together, these statements provide a still deeper understanding of the importance informal communities and the building of networks play in big pharma.

5.3.4 Transformation of knowledge

Subsequent to the finding that there are few formal processes in place to assimilate newly acquired knowledge from collaborators across firms, the investigation into the key processes that allow firms to transform new knowledge focused on 'new knowledge' in general. Interestingly, apart from one scientist, most of the interviewees showed great difficulty sharing their insight into this.

Of the findings that were obtained from the scientist in question, transformation of knowledge seemed to be dependent on a combination of biological science to identify targets in general and an understanding of what targets would be most applicable using, for instance, a new technology to screen compounds. Applying this to the context of collaboration, it appears that transformation of knowledge is dependent on the quality of the acquired knowledge.

Although the difficulty of answering this could have been caused by the generality of the question, the fact that so many interviewees had problems answering provides an indication that the answers to this question relied on the scientists' tacit knowledge and, as such, confirms the theoretical assumption by Lane *et al.* (2002).

5.3.5 Exploitation of knowledge

Whilst the investigation into 'transformation' of knowledge to some extent seemed to rely on tacit knowledge, the interviewees appeared to be more aware of the processes that enable them to exploit knowledge. i.e.: 'proof of concept' and 'quality by design'.

Interestingly, most of the interviewees regarded "validation" in terms of a proof of concept as the key measure to help them decide whether to exploit this. Proof of concept is explained below:

"Proof is: identify what it means to do, test to see if it does that, and if it is still standing, take it further". (Scientist, GSK)

As emphasised by several interviewees, it is after the proof of concept period that a compound goes into development. As indicated by the same scientist, although different drugs might have different requirements for development, development usually relies on big pharma's own knowledge and capabilities.

In addition to 'proof of concept', a scientist at Pfizer stressed the importance of using the method of 'quality by design'. According to this scientist, quality by design is an FDA driven initiative to reduce the extensive amount of testing of the end product *"as this drives up the costs, it drives up R&D and it drives up the time"*. FDA designed this method acknowledging that other industries seek to build quality into the products from the start,. Asked more specifically what quality by design is, the scientist came up with the following explanation:

"I can get quite technical about this but it has to do with the design, e.g. if you know that it is only in one temperature that things work, you pick the whole design window and then you know as soon as you operate within that quite wide window you know you have a

quality product. And what you're doing is that you're testing the quality into the product from day one and then you are quite safe that you have good drugs at the final end".

Table 5.1 summarises the key processes that enable a firm's knowledge acquisition, assimilation, transformation and exploitation as found in the cross case interviews.

Table 5.1: Key processes for knowledge acquisition, assimilation, transformation and exploitation

Routines and processes	Formal processes	Informal processes
Identification of potential collaborators	Business development department - attends biopharma conferences and forms relationships - produce brochures - receive applications - use of scouts	- Scientists' own network. Networking at conferences particularly important as it allows scientists to meet other scientists, and follow up these contacts in their future work.
Evaluation of knowledge and potential for collaborative success	- Scientific background - Business development team - The knowledge of the scientists makes them the only ones in the firm who can fully evaluate the importance of external knowledge. - External consultants **Criteria for evaluating collaborative success:** - Scientific expertise of partner - Complementary skills – a 'fit thing' - A shared culture and values - Mutual aspirations - Possibility to build trust	- Scientists often rely on their own personal network when evaluating work in new and complex areas.
Acquisition of knowledge	- Prior knowledge - Supportive environment for knowledge sharing and flexibility of knowledge - Sheer number of scientists - Set up databases - Face-to-face meetings	
Assimilation of knowledge	- Sharing of ideas in formal teams that scientists are put to work in - IT system - Organisational charts, which help to connect people - 'Stalls to sell' knowledge	- Sharing ideas in informal communities, formed on the basis of interests - Word of mouth. A Head of R&D sees word of mouth as quite impressive, explaining that one of the core competences in such a large firm is finding one's way through it

Transformation	N/A	N/A
Exploitation	-Proof of concept -Quality by design	Personal judgements and validation of data

5.4 Summary of findings

The growing scope of research and the change of knowledge base over recent decades provide a deeper understanding of big pharma's growing reliance on collaborations. Due to the growing importance of collaborations and the fact that big pharma is predominantly responsible for the latter stages of drug development, the research finds R&D changing role, i.e.: the key role of R&D is to identify and evaluate collaborators and develop externally invented candidate drugs. Interestingly, whilst this new role of R&D matches the definition of absorptive capacity, the research also shows that this role is dependent on an investment in R&D, which is in direct congruence with Cohen and Levinthal's theory (1989, 1990, 1994) of absorptive capacity. The enquiry into the key processes enabling identification and evaluation added to this understanding of the importance of R&D by respectively highlighting the importance of scientists' own network and basic knowledge. Putting together the growing importance of collaborations and the fact that the key role of R&D is to identify and evaluate collaborators, the research shows a clear dynamic relationship between R&D and collaborations.

Interestingly, however, despite the finding that collaboration is an important knowledge acquisition strategy but is also used to enter into new areas, this strategy seems to have little impact on big pharma's capability building. Wholly unexpectedly, the interviews indicated that it is the small firms that seek to learn from the large firms, rather than vice versa, in option-based collaborations. Despite the scepticism towards collaboration's potential to improve firms' innovative capabilities, and the understanding that acquisitions

seem to be more suitable to obtain a 'definite position' in a new area, the research suggests that collaborations can have a positive impact on innovative capabilities if certain criteria are met: i.e. large scale, complementary skills and supportive culture. Interestingly, whilst some of the key factors seem to have a direct impact on a firm's ability to acquire knowledge from a collaborator, the investigation into the key processes enabling the subsequent assimilation and transformation of that knowledge is challenging, particularly as there are few formal measures in place for assimilating knowledge around big pharma and that transformation primarily seems to rely on tacit knowledge. Exploitation, on the other hand, seems to rely on specific measures used to build quality into the product (quality by design) and evaluate the effectiveness of the drug (proof of concept).

Chapter 6:

Case study

6.1 Introduction

This chapter seeks to present the findings obtained through the case study on how AstraZeneca (AZ) actively formed large scale collaborations with external partners, i.e. US based Abgenix and UK based Cambridge Antibody Technology (CAT) in order to move into the area of monoclonal antibodies (MAbs).

As discussed in chapter three, the aim of the case study is to investigate the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge from a collaborator (i.e. *research question two*). However, the fact that large scale collaborations were used as means to enter into new areas also makes the case study an ideal way to investigate how important this type of collaboration is for building new innovative capabilities, and, as such, serves as an illustrative case for *research question one*. It is important to note that, although forming collaborations with external partners was AZ's chosen strategy for entering into MAbs, AZ ended up acquiring one collaborating firm, i.e. CAT, in addition to MedImmune, making AZ a vertically integrated biologics company. As will be shown in this chapter, the fact that AZ did acquire CAT and MedImmune is used to evaluate the respective effects of the collaborations.

In order to present the necessary information on the different collaborations, this chapter seeks firstly to provide the background to AZ entering into large scale collaborations to move into MAbs (6.2), the key processes involved in identifying and evaluating firms (6.3) and the nature of the deals (6.4), before focusing more explicitly on the effects of the different collaborations (6.5), their distinctive success factors (6.6) as well as the key processes behind the knowledge transfer between AZ and the collaborators (6.7).

6.2 Background for entering into large scale collaborations to move into MAbs

The extract below, which is taken from a public talk by the CEO of AZ, 'sets the stage' for the case study, introducing not only the perceived importance of entering into monoclonal antibodies, but hinting at AZ's active engagements with external firms, i.e. CAT and MedImmune, as mentioned above.

"Our heritage, traditionally from Astra and Zeneca before the merger, was small molecules, taken from natural sources [...]. Mainly the new opportunities, and certainly the development of the world pharmaceutical market in the last few years, have been large molecules: biologics, monoclonal anti-bodies. We formed partnerships with CAT a couple of years ago, which was based here working on monoclonal antibodies, [and then acquired] a fully integrated biologics company: MedImmune. They have a very successful track record of bringing drugs to the market, and have [a] multi-billion franchise in viruses".

As illustrated in the above quote from the CEO of AZ's public speech, the 'heritage' of AZ before the merger was small molecules. However, a couple of years into the merger (2001), which had made AZ the fourth biggest pharmaceutical company in the world, the company sought to widen its research focus and, according to a Senior Manager in R&D,

formulated a strategic aim that it *"would enter into biologics as a company"*. As illustrated by the CEO in his talk, the decision to enter into biologics reflected the growing opportunities for the use of large molecules. On the other hand, several interviewees highlighted that AZ, at this time, was *"behind competition in this area and needed to act"* (Senior Manager in R&D, AZ).

According to a Senior Manager in R&D, the choice of entering into MAbs reflected several parallel activities.

Firstly, as part of the strategy of entering into biologics, AZ had formed a group that was spanning the opportunities in biologics. Given the increasingly important role MAbs had specifically played in cancer research over the 1990s, as well as the development of monoclonal antibody technologies, the group *"formed the view [...] antibodies were an area we needed to get into with AZ"(Senior Manager R&D).*

Secondly, a research group in the oncology therapy area had, at the time, just started to look at ways to exploit MAbs in their projects. An interview with the scientist who led this group, and who later became the lead scientist for the Abgenix collaboration, revealed that although AZ had been involved in projects with the Cancer Research Campaign, and had itself tried to initiate a couple of projects in the area, the company had *"little prior experience with MAbs"*. An interview with another Senior Manager in R&D at AZ emphasised the importance of the initial work led by the lead scientist for entering into MAbs, saying: *"eventually, this work was pushing it through"*

The following statement made by the lead scientist illustrates not only AZ's limited capabilities in MAbs but also the perceived importance of it:

"I led a group which looked at potential ways of, [...] trans-start oncology activity in monoclonal antibodies, because [...] we had limited activity prior to that doing quite a specific project with organisations like cancer research campaign, [when] we had looked at antibodies. Over the previous 15 years or so we've had a few, one or two, individual projects, none of which had really come through to fruition, because it was a little bit early before antibody technology had [come out]. It was something we were keeping an eye on but, as I said, decided back in, I guess, 1992 [...] that this was something we needed to really have a hard look at".

Putting these parallel activities together, it was decided that the Oncology therapy area *"would lead the way"* in AZ's efforts to obtain capabilities in MAbs. According to the same Senior Manager in R&D, the decision to form a large scale collaboration with one external player to enter this area rested upon a common perception that they *"needed something bigger"* than what they would be able to do themselves. In addition to this, the choice of entering into a collaboration to move into MAbs reflected a more general perception that it would take too long to build capabilities in-house and, as such, collaborations would be a more efficient way of entering the new area.

6.3 Key processes involved in identifying and evaluating firms and formulation of deals

With the strategic decision to use a large scale collaboration to enter into MAbs, AZ's Alliance Management department was set to manage the process of identifying a suitable firm, and to initiate the subsequent negotiations with it. As mentioned in chapter 5, since the mid-1980s most big pharma firms have formed special departments whose task is to manage external partnerships.

An interview with a Senior Manager in Alliance Management showed that, as part of the process of identifying a suitable firm, the Alliance Management team required the scientists to make a judgement call on the technology they favoured, who provided it, and who would be the best partner. Interestingly, the fact that the Manager stressed the importance of firms' technologies for producing MAbs seems to confirm the finding obtained in the cross-case interviews that 'scientific expertise' is a key criterion when choosing a collaborator.

"We did a judgement call on which technology we favoured and who provided it, the make-ups of the companies and certainly who would be the best partner. And that partner was Abgenix".

A later interview with a Senior Manager in R&D provided further details of the process of identifying a suitable firm, showing that AZ had *"looked into several firms"* when choosing a suitable partner, including CAT, which would be the next firm with which AZ would enter into a large scale collaboration. The quote also confirms that the firms' technologies for the production of MAbs were used as AZ's key criterion for selecting its partner.

"So we looked at various companies [...]. The idea was to identify a company where we could springboard some major activity. We could obviously have started a couple of projects ourselves; we probably had some capability to do that, in reality. I guess we all felt that we needed something slightly bigger. We had a look at a number of companies at the time, including CAT at the time and we also looked at Abgenix as a company. We decided on Abgenix as our first move forward, because at the time we were looking, there were quite a lot of IP issues around the field around the antibody display technology, which is what CAT's expertise was. Although this was getting settled by the time we did the

deal with Abgenix, we had gone a long way down the track with Abgenix. We did feel that their technology was very powerful and we decided to continue in oncology with the Abgenix deal, which would springboard us in terms of getting our portfolio of projects in the oncology area in monoclonal antibodies."

As soon as the decision was taken, the Alliance Management department contacted Abgenix and initiated both the negotiation process and due diligence. An interview with a Senior Manager in Alliance Management in AZ revealed a hard negotiation, as illustrated in the quote below:

"It took us a couple of years actually to put the deal together, which created some frustration, but in the end we got what we wanted, which was a fairly all-encompassing deal"

Finally, in 2003, AZ's Oncology therapy area formed a large scale collaboration with US based Abgenix. As illustrated in the following statement, the aim of the collaboration was to discover fully human MAbs for the treatment of cancer. The collaboration was regarded as a complementary activity to AZ's work in small molecules.

"The collaboration with Abgenix Inc started in 2003 and aimed to discover fully human monoclonal antibodies for the treatment of cancer. The collaboration was complimentary to AZ's activity in small molecules and allowed them to tackle a broader range of targets[17]".

As seen above, CAT had been rejected as AZ's choice of partner for the initial collaboration. Interestingly, the same year as the Abgenix collaboration started, CAT approached AZ with the intention of forming a collaboration agreement. AZ's Alliance

[17] Explanation of target (see chapter one)

Management department played a central part in taking the CAT 'application' forward and after consulting strategy and the biologics group, AZ saw this as an opportunity to further its strategy of obtaining capabilities in MAbs. However, due to the exclusivity[18] of the Abgenix collaboration in Oncology, AZ proposed a large-scale collaboration in Respiratory and Inflammation (R&I), which was accepted by CAT.

An interview with a Senior Manager at the former CAT revealed that the underpinning reason that drove CAT to approach AZ was that CAT was experiencing some financial uncertainty, caused by a dispute with another firm regarding a royalty payment for one of their key products. Hence, forming a more permanent collaboration, ideally with a big pharma firm, was seen as an attempt to bring some stability to the business. Further reason for approaching AZ was that CAT had had previous collaborations with AZ, giving them an appreciation of AZ's mentality and an awareness that AZ was actively seeking to get into biologics. On another note, information about litigation in which CAT was involved at this time, shared by the Senior Manager, seems to provide more insight into the IP issues that had prevented AZ from approaching CAT for the initial collaboration (see quote above). The points above are illustrated in the following quote:

"Now there were various factors around 2003 – 2004 that made our revenue stream slightly more uncertain. We were in litigation with others about a royalty rate for Chemira, the drug Chemira, and we had an agreement around royalty payments. There was some uncertainty around what level of royalty payment they would provide us with, so there were some external factors which made the business model more uncertain and we actually took a business decision that CAT [would] go and find a more permanent or a more secure strategic partnership, ideally with a big pharmaceutical company. There was a need for us to bring some more stability to the business, so that was sort of the reason

[18] More on the exclusivity of the Abgenix collaboration under *"Nature of the deals"*

why we started talking to AZ, and we had already done some work with AZ on a small project historically, we had a relationship with AZ and the fact that AZ operations were in Europe and the UK, they were high contenders to sort of go out and talk about[...]. I think we also understood that, you obviously have to ask them about what drove them from their side, but AZ was going through a realisation that biologics are a very, very valuable drug class. They needed to think about how they were going to access antibodies [...] technologies, we were looking very actively at that as well, so I think it was a meeting of minds. We didn't just talk to AZ but AZ was always frontrunners [...] for various reasons around relationships, mentality, business need and in the end, it worked out very well".

As illustrated in the following quote, AZ formed a long term collaboration with CAT in R&I with the aim of generating monoclonal antibody therapeutics. The quote also provides further insight into the perceived importance of CAT's technology.

"In December 2004, AZ and Cambridge Antibody Technology entered into a five year discovery alliance to generate monoclonal antibody therapeutics principally in inflammatory disorders, including respiratory diseases. For AZ, this collaboration provides access to leading technology for the generation of fully human monoclonal antibodies for application across all relevant disease areas, working alongside a leading company in the field".

As illustrated in the following quote, within the space of two years AZ entered into two large scale therapy area deals with two different firms.

"We did two key deals. We did an oncology deal with Abgenix, and a year later we did a major collaborative deal with CAT in the respiratory and inflammation area, so they were therapy area focused deals initially"

Reflecting upon the process leading up to the deals, it is interesting to note that although it was AZ's Alliance Management department that was set to manage the process of identifying and negotiating the first collaborating firm, i.e. Abgenix, as well as taking CAT's 'application' forward, the actual evaluation of the scientific expertise of the candidate firms was carried out by the scientists. Whilst the latter is fully congruent with a finding obtained in the cross-case interviews, showing that 'evaluation' requires some basic understanding of the field, the fact they used scientific expertise to range the potential collaborators shows that the scientists were seeking to "pin down" the experts in the field, which in the cross-case interviews was regarded as the key criterion for forming a collaboration with an external firm (illustrated in the quote below the document analysis).

Interestingly, investigating Abgenix and CAT's expertise, through a document analysis based on documents published a couple of years before the initiation of the respective collaborations, shows that both were world leaders in their fields (see extracts below). It is important to note that some bias might be present as the sources behind the documents are the firms themselves. However, the fact that both have antibody product candidates in human clinical trials objectively illustrates that the firms, at the time they entered into the collaborations, had developed strong capabilities in developing MAbs.

In 2002, a year before entering into the collaboration with AZ, Abgenix presented itself on a website called BioSpace, as "a leading company of the development and commercialization of antibody therapeutic products for the treatment of such conditions as transplant-related diseases, inflammatory and autoimmune disorders, cardiovascular disease, infectious diseases, and cancer". Explaining its technology, the company states: "we use our proprietary XenoMouse™ technology to enable the rapid generation of high affinity, fully human antibody product candidates to essentially any disease target appropriate for antibody therapy", and claims that, "the XenoMouse™ technology has

been the gateway to building and commercializing a large and diversified product portfolio through the establishment of corporate collaborations and internal product development programs". As a further point, the company claimed that, at that particular point in time, it had four antibody product candidates in human clinical trials (Biospace, 2010).

In the same year (2002), an interview with the Medical Director of CAT, David Glover, was carried out by Alex Crawford on behalf of Bioportfolio. The interview gives not only a background of CAT, but inquires into the company's own claims of being a world leader in the field. As a response to the latter, the Medical Director stated: *"World leading! World's best! Some of the factors that lead us to believe that we are world leading—and it's not just us that we believe it, but pharmaceutical and biotech companies back our technology, and the analysts all believe that we are world leading as well—it's just that we pioneered the whole field in the first place. We did the very first experiments that showed that you could express monoclonal antibody on the surface of phage. So we're pioneers, that's the first thing. Secondly, we're leading from the point of view that we have more candidates in trials than any other company using phage-display technology. In fact, we've got more than all the rest of them put together in the whole world"* (Bioportfolio, 2002).

Whilst the process of identifying Abgenix clearly illustrates the first criterion in the quote below, CAT provides an illustrative case for the second and third criteria.

"It is my global perception of the disease and that's absolutely crucial. Who are the people, the experts, the biologists and so on who are working in that area? That is crucial. That's my number one – my ability to [pin down] the absolute capacity position – that's absolutely crucial in terms of a collaboration. Second to that but very, very close to it, does it match with the skills I've got? The capabilities and needs I've got internally? Is this something that doesn't fit at all? The third thing, and I think again it is very close, is the

culture thing. If I go there and I talk to them, is there chemistry? Is it likely to work? Can I build trust? Can I build a sense of joint-ness? Because only in that way can I build a really competitive activity and really utilise that collaboration".

In terms of capabilities, it is interesting to note that, the two companies having worked together previously, CAT knew that AZ was seeking to enter into biologics. On the other hand, although it was financial uncertainty that drove CAT to seek a strategic partnership, it is interesting to note that one of the reasons for choosing a big pharmaceutical firm was that CAT had never taken any of their drugs to the market and recognised big pharma's expertise in this area. The latter provides a deeper understanding of the finding obtained in the cross-case interviews, i.e. that small firms seek to learn from big pharma firms.

Apart from complementary business needs, the fact that CAT considered AZ as *"frontrunners [...] for various reasons around relationships, mentality"* (taken from a quote made by a Senior Manager at CAT, above) further illustrates that CAT recognised that a collaboration could work. In this context, it is interesting to note that an in-depth interview with a Senior Manager in R&D at AZ revealed that the first meetings with CAT worked particularly well, and that CAT and AZ felt *"culturally attuned to each other"*.

Interestingly, whilst chapter 5 emphasises the importance of big pharmaceutical firms carrying out due diligence on small firms, an interview with a Senior Manager in CAT revealed that both AZ and CAT had carried out a pre-deal assessment on each other. As illustrated in the following quote, it is rather unusual for a small firm to carry out a due diligence on a large firm like AZ. CAT's decision to carry out a due diligence on AZ was based on the consideration of the risks of entering into a strategic alliance as well as their financial problems and, as such, carrying out a due diligence was a concrete measure to make sure they were choosing the right partner. As illustrated in the following quote,

although unusual, CAT gained a lot of respect and credibility from carrying out a due diligence. Hence, it seems like carrying out a due diligence in itself contributed to the creation of a positive relationship between AZ and CAT.

"You have to understand from a CAT perspective, it was a real risk for us as a business to go into a strategic alliance [...]. AZ came to do a due diligence on CAT as part of the strategic alliance but we actually also went up to AZ and did a bit of due diligence on AZ, because we had an interest in coming into a strategic partnership and we were very, very determined to find out which partner would have the best fit, that we thought would work. So even though we were only a small company [...] we actually did a due diligence on AZ, which actually took them a little bit by surprise, which obviously gave us a lot of credibility and respect".

6.4 Nature of the deals

As mentioned above, as a pronounced strategy of entering into MAbs, AZ entered into two exclusive large scale collaborations, with Abgenix in 2003 and CAT in 2004, respectively in the Oncology and Respiratory & Inflammation therapy areas. This section seeks primarily to provide insight into the nature of the deals but also into the implications the deals had for the parties involved. The investigation rests upon both a document analysis and interviews, with document analysis providing an understanding of the exact terms underlying the collaborations, and interview data then used to provide a deeper insight into some of the points in the agreements, as well as into the implications the agreements had for all the parties involved.

Table 6.1 The principal terms underlying the Abgenix and CAT agreements

Partner and type of collaboration	**Abgenix** – a broad collaboration, license and investment alliance	**CAT** – a joint discovery and development alliance
Targets	The alliance seeks to discover, develop and commercialize 36 fully human monoclonal antibodies to treat cancer. In addition to this, AZ is entitled to select from an additional pool of antibodies by Abgenix.	The alliance will include a five-year discovery initiation phase during which the partners will jointly initiate a minimum of 25 discovery programmes, principally in inflammatory disorders, but may extend to other therapeutic areas. AZ will also receive the rights to opt-in to, and develop jointly, CAT discovery programmes existing at the commencement of this alliance and also certain future discovery programmes that CAT may independently initiate.
Responsibility	Financial responsibility: a $100 million investment by AZ in Abgenix convertible preferred stock. Upon the achievement of certain milestones, Abgenix may also require AZ to invest an additional $60 million in Abgenix convertible preferred stock. The development of the additional pool of antibodies is, on the other hand, based on an equal cost sharing basis. Responsibility of work: Abgenix will conduct early clinical trials, process development and clinical manufacturing, as well as commercial manufacturing during the first five years of commercial sales. AZ, on the other hand, will be responsible for late stage clinical development of the portfolio.	Financial responsibility: both AZ and CAT commit a joint research investment on a minimum of $175million, which the parties will fund 50:50. Following the completion of the discovery phase, the parties may each elect to continue funding programmes into development. In addition to this, under a separate Subscription Agreement, AZ will subscribe in cash CAT's shares for a 19.9% interest in the enlarged issued share capital of CAT. Responsibility of work: CAT will be principally responsible for antibody discovery, manufacturing process development and the supply of material for exploratory clinical trials, whilst AZ will be principally responsible for translational biology, clinical development programmes, regulatory filings and commercialisation. However, joint teams will be established to oversee the full discovery and development process.
IP issues	AZ holds exclusive commercialization rights for the initial 36 product candidates. Abgenix will receive milestone payments at various stages of development and royalties on future product sales. In terms of the addition pool of products, given the equal cost sharing of the, these products build on an equal profit sharing basis.	CAT's financial participation reflects its level of investment in the programme. If CAT opts out after the discovery phase it receives milestones and royalties. If it opts-out at Clinical Proof of Concept it receives milestones and royalties at a higher level. CAT has the option to continue to fund jointly the development of one in every five products that reach Clinical Proof of Concept up to product launch. For these programmes CAT receives higher royalties, sales milestones and an option to co-promote these products in the US. If AZ opts-out of programmes it receives milestones and royalties. In terms of the products resulting from the programmes existing at the commencement of this alliance and also certain future discovery programmes that CAT may independently initiate, CAT has the rights to co-promote them in the US.

Sources: Amgen (2003) and Bioexchange (2004)

Table 6.1 is based on a document analysis of key communications announcing AZ's strategic partnerships, first between AZ and Abgenix and then between AZ and CAT, and outlines the principal terms that were set out in the initial agreements. In summary, the table shows that although AZ acted as the principal beneficiary in both the collaborations, AZ's collaboration with CAT clearly opened for a deeper involvement of both the parties on all aspects, i.e. the responsibility of work, investments, options and IP issues, than did the collaboration that AZ formed with Abgenix. Clearly, this must be seen in relation to the nature of the deals underlying the collaborations, whereby the CAT collaboration was based on a *'joint discovery and development deal'*, whilst the Abgenix collaboration, on the other hand, was regarded as a *'broad collaboration, license and investment alliance'*. The interviews sought to go beyond the merely formal aspects of the deals, particularly seeking a deeper understanding of: i) the underlying reasons for entering into such different deals (6.4.1), ii) the aims, structure and implications of the collaborations (6.4.2).

6.4.1 What were the underlying reasons for entering into such different deals?

As seen above, although the two collaborations differed in nearly all respects, the focus of the interviews was principally to understand the distinctive differences of the deals' responsibility of work. The collaborations with the different firms will be presented separately, starting with Abgenix.

Abgenix

As seen in table 6.1, except 'for late stage clinical development of the portfolio', Abgenix was responsible for the discovery and development of targets. Interviews with a Senior Manager at AZ confirmed 'responsibilities of work' between the partners, as illustrated in the quote.

"The deal was both: discovering the targets and initially the idea was that Abgenix would help us to develop the antibodies through and into the clinical development and beyond, incorporating potential access to their manufacturing capability".

According to one of the Senior Managers in AZ, due to the fact that the deal incorporated access to Abgenix's manufacturing capability, the collaboration was regarded as a *'Co-development and beyond agreement'*.

The fact that the Abgenix collaboration incorporated access to Abgenix's manufacturing makes this collaboration rather unusual in comparison to most big pharma-small biotech collaborations, where the small firm is responsible for the research and the large firm is responsible for development (see chapter 5).

According to an in-depth interview with a Senior Manager in R&D, the choice of incorporating access to Abgenix's manufacturing reflected AZ's complete lack of experience in developing biologics [in which] *"we clearly had no knowledge"* and which made them rely on Abgenix's expertise in this area. The interview reveals that Abgenix had built up experience in the later stages of the development, pointing to the fact that: *"They had experience at that point, they had a late stage EDFR receptor antibody that was in a phase 2 trial which eventually has gone on and been registered as a drug".*

CAT

As seen in figure 6.1, 'CAT will be principally responsible for antibody discovery, manufacturing process development and the supply of material for exploratory clinical trials, whilst AZ will be principally responsible for translational biology, clinical development programmes, regulatory filings and commercialisation' .

Whilst a simple comparison of AZ's responsibilities of work in the CAT collaborations with those in the Abgenix collaboration shows that AZ was more involved throughout the product development in the CAT collaboration, this was further confirmed in the interviews, as illustrated in the quote below.

"We had a model where we did a lot of the early work in collaboration with the biologists, pharmacologists and gradually AZ [at] the later stage". (Senior Manager, CAT)

In terms of development, it is interesting to note that although CAT was responsible for manufacturing, which in itself provides yet further evidence for AZ's lack of manufacturing expertise in biologics, the interviews interestingly revealed that CAT had a limited capability in manufacturing and in the later stages of product development. The larger involvement on the part of AZ, particularly in development, than in the Abgenix collaboration must, therefore, be seen as a direct result of CAT's limited capability in the later stage development.

The first indication of CAT's limited capability was obtained in an in-depth interview with a Senior Manager at CAT, showing that although CAT had a mixed business model where they sought both to license their technology and to build their own proprietary pipeline, they had little experience developing MAbs, as illustrated in the following two quotes.

The quote below illustrates CAT's mixed business model:

"Our business model was a mix[ed] business model, so we had a [customer base] based around licensing our technology. We had big in-licensing agreements in place with a number of pharmaceutical companies, like Amgen, Genentech. Then we licensed the technology to bring in revenues, so we got royalties from that sort of business. And then we used that trying to build our own proprietary drug pipeline".

The interviewee then added:

"We had never really taken anything all the way through to the market as a stand alone company".

CAT's limited capability in manufacturing was further confirmed in an in-depth interview with a Senior Manager in R&D, AZ, showing that CAT had been using contract manufacturers for the large scale manufacturing, as illustrated in the following quote:

"CAT were like us using contract manufacturers for the large scale manufacturing; [them having] small scale manufacturing capabilities."

Interestingly, whilst section 6.3 gives some indications that CAT and AZ sought complementary skills when forming a collaboration with each other, the above shows that the deal's division of responsibility of work builds on the distinctive capabilities of the partnering firms.

Overall, because CAT was responsible for antibody discovery, most of the early phase was carried out at CAT, whilst the fact that AZ was responsible for 'clinical development programmes, regulatory filings and commercialisation' suggests that that the collaboration followed a more typical pattern for big pharma-small biotech collaborations than the Abgenix collaboration.

6.4.2 Aims, structure and implications of collaborations

The documents provide a first insight into the aims of the different collaborations, showing that AZ's collaboration with Abgenix aimed at initiating 36 projects in three years, whilst CAT sought to initiate a minimum of 25 projects in five years.

Interestingly, interviews with several Senior Managers in AZ and CAT revealed that both the Abgenix and the CAT collaborations were structured around the targets, where the work on reaching the target would be overseen by one representative from each of the partnering firms, i.e. AZ and CAT or AZ and Abgenix. This provides deeper understanding of what was meant by 'co-development'.

However, given that CAT and Abgenix were set to discover the targets and subsequently manufacture the MAbs, AZ took up big resources at both the firms. As illustrated in the quotes below, whilst AZ bought into 200-300 employees at Abgenix, *"it took up 150 employees at CAT"*. Although there was some uncertainty regarding the number of employees involved in the collaborations, there seemed to be a general agreement that that about 40 people were working in each of the collaborations. In addition to the time involved in the collaborations (i.e. three and five years), the latter illustrates that AZ showed a clear commitment to both the collaborations.

In both cases, AZ negotiated exclusive deals with its partners. As illustrated in the quote below, this meant that neither Abgenix nor CAT could work with any other partners in these areas, respectively Oncology and R&I. Interestingly, the exclusivity of the deals was enforced through their structure, i.e. the way the collaborations were structured around targets, it would be hard to work with external partners (see quote below). Furthermore, CAT's deal with AZ implied that CAT had to ring-fence its activities with AZ.

"The Abgenix deal would springboard us in terms of getting our portfolio of projects in the oncology area in monoclonal antibodies, so the deal was structured, we had agreed that we would process 36 oncology targets over a three year period, in terms of actually starting 36 projects in a three year period. We were taking up a large chunk of the Abgenix resource effectively, an exclusive deal with Abgenix in Oncology, and they couldn't work

with any in Oncology after they had signed the deal in Oncology. And the way the deal was [structured] around targets, it would have_been quite hard to work with anybody else on any other target, so we entered a quite exclusive or fairly exclusive [deal], where we were using an awful lot of the Abgenix capacity at the time. We bought into approximately 200-300 people [...]. The deal was both: discovering the targets and initially the idea was that Abgenix would help us to develop the antibodies through and into the clinical development and beyond, incorporating potential access to their manufacturing capability as well, so it was a large deal".

The quote below provides insight into the negotiation of the CAT deal.

"AZ was incredibly clear that it needed the freedom to work in a collaboration with CAT across the respiratory and inflammation area and it needed the ability to start a certain number of projects each year. [...] CAT was equally clear that it was working on oncology in an area in which AZ was a competitor, so it [split] off its oncology activities etc and kept it completely separate. And because it still believed ultimately that it was going to be independent and that the collaboration would just yield some very valuable co-development opportunities in R&I, CAT believed that it could work in all the other areas. It had a pain compound where [it was] partnered with Elan, it had some oncology compounds going on etc, etc. So you know, culture, mutually defined aspirations that are really stretched out to be as specific as possible and a very, very clear view on scope. Now it turned out, of course this goes back to the big-little thing, that CAT has got 300 people, which is quite big to be a biotech but nevertheless we wanted 50% of their R&D capacity, you know, we were not up at this time, we just didn't want one project, and [...] obviously CAT had to go back to its business team and decide whether it was prepared to get so deeply involved with one player and, you know, that's where the discussion [was]. [So], those are a few of those things and I think, you know, if you've done these things a few

times both companies, the framework for the agreement and the terms becomes actually a little easier".

Interestingly, whilst the CAT collaboration was originally limited to R&I, the idea of extending the collaborations to the Oncology therapy area was taken forward and later approved. This decision rested on the importance MAbs play for Oncology. However, as the deal with Abgenix excluded Abgenix from the possibility of working with third parties on the set targets, AZ decided that the CAT collaboration could only work on targets that were not part of the Abgenix collaboration. The following quote seeks not only to illustrate the latter but holds Abgenix's deals with other pharma firms as the key reason for Abgenix not taking onboard certain targets.

"We were asking Abgenix to be exclusive to us in oncology and obviously they wanted us to be fairly exclusive to them, so we couldn't really have worked with another partner on oncology, except on targets that Abgenix couldn't work with us on, because they had partnered with other partners before the deal. Abgenix had a whole range of other big pharma partners".

Given the importance the targets played for the collaborations, it seemed obvious that the interviewees highlighted that reaching these targets was the ultimate aim of the collaborations. However, clear indications that the large number of targets, and the way the collaborations were structured around them, reflected the strategic goal of creating a portfolio of products in MAbs, prompted an investigation into the extent to which the collaborations were motivated by learning.

The inquiry into learning with Several Senior Managers at AZ and CAT provided quite interesting findings, particularly related to the Abgenix collaboration.

On the one hand, when investigating the extent to which the Abgenix collaboration was motivated by learning with a Senior Manager in R&D at AZ, the response was overwhelmingly positive, with the view that AZ's collaboration with Abgenix was a springboard to buy into Abgenix's capabilities, expertise and knowledge. On the other hand, when inquiring further into this with a Senior Manager at CAT, working on targets in Oncology that were not part of the Abgenix deal, the interviewee showed great scepticism, taking the view that the way the collaboration seemed to work was more as a contract research agreement. Although this could be a reflection of the nature of the deal, the statement must be treated with care, particularly since the interviewee was not directly involved with the collaboration, and represented another, perhaps competing, collaboration.

The quotes made by the Senior Manager in R&D at AZ and the Senior Manager in R&D at CAT are shown below:

"Yes, it was, it was a springboard. We didn't just buy into the 36 targets, we were buying into their [Abgenix's] capability, expertise and knowledge of developing biologicals. They had clinical manufacturing experience, so we were buying into a combination of technological ability to generate and lead antibody projects, and we felt that the technology was world leading at the time, and obviously a wealth of experience".

"I was working in the oncology area when we started the collaboration with AZ oncology and I saw a lot more of how the Abgenix collaboration was working and it was much more a kind of contract research agreement than joint collaborative way of working, so Abgenix were [told] ... 'yeah, here's your targets to go away with and make some antibodies', then they were brought back into AZ, [it was] clearly more delimitating".

Interestingly, when inquiring into the importance of learning for the CAT collaboration with a Senior Manager in CAT, the manager emphasised that the collaboration had served as a springboard for learning not only for AZ but also for CAT, emphasising the finding that small firms actively seek to learn from large firms. Though the following quote is a direct answer to the question of the extent to which the CAT collaboration was motivated by learning on the side of AZ, the answer also illustrates that the collaboration served as a springboard for both AZ and CAT.

"Definitely, definitely! In R&D, definitely! They [AZ] knew what they could do, they knew where their gaps were, they were honest and realistic about that and likewise we were, and that was what really gave us a good springboard"

6.5 Effects of the collaborations

This section seeks to present the respective effects of the collaborations.

The underlying investigation sought firstly, due to the importance targets played for both the collaborations, to investigate how effective the collaborations had been in reaching these targets. Then, due to the indications that the collaborations were motivated by learning, the research sought to better understand what, if anything, was learnt. Finally, as mentioned in the introduction to this chapter, provided that the collaborations were used as means to enter into the area of MAbs, the research sought to investigate the importance these collaborations had played for AZ's capability building. Insight into the latter was primarily sought by inquiring into the extent to which AZ has started up projects on the basis of what they have learnt. In addition to this, as mentioned in the introduction 6.1, the effects of Amgen acquiring Abgenix in 2005 and the underlying reasons for AZ to acquire CAT in 2006, as well as MedImmune, which was one of the biggest vertically integrated

biotechnology firms, in 2007, are used to provide further insights into the respective effects of the collaborations.

Seeking firstly to present the findings obtained through a direct investigation into the effects of the collaborations, i.e.: i) effectiveness of reaching targets, ii) learning and iii) capability building (6.5.1), this section then concludes with insights into the effects and underlying reasons for subsequent acquisitions (6.5.2).

6.5.1 The respective effects of the collaborations

As mentioned above, this section seeks to present the findings obtained through the investigation into the above mentioned points for each of the collaborations. The points will be presented as research findings.

Abgenix

- *Targets and effectiveness*

Several interviews with Senior Managers in both R&D and Alliance Management have confirmed that the Abgenix collaboration managed to reach its initial aim of initiating all of its 36 projects within the set time frame of 36 months. Though it is still too early to say how many of these projects will turn into marketable products, interviews with several Senior Managers at AZ not only confirmed that most of the projects have, so far, survived but also that some of the early products have now entered into clinical development, as illustrated in the following quote:

"Some of those [36] targets have progressed through and are just entering into clinical development, so some of them have gone all the way through and are about to start to enter into patients".

The fact that the collaboration managed to reach its targets on time objectively illustrates the effectiveness of the collaboration. However, when inquiring directly into the efficiency of the collaboration, a Senior Manager in R&D at AZ emphasised the fact that the collaboration had reached a high number of targets with a sparse resource. Interestingly, although hinting at their managerial efforts, the manager stressed that it was the new area (i.e MAbs) that allowed the initiation of such a large number of projects by a relatively modest resource, stating that they would have needed ten times the level of resources to initiate projects in small molecules, as is emphasised in the quote below. The latter was further highlighted as one of the key reasons why they wanted to enter into this new area in the first place, as illustrated in the second quote below:

"I think people here see it as a very successful collaboration. I think we were amazed that we managed to get 36 projects going over three years. We were a very small resource in AZ, we probably had 40-50 people, so to develop 36 projects with that number of people... you know... if compared to what we need in small molecules, it would probably be ten times that!"

- Perceived learning

Inquiring into the effects the collaboration had on learning across AZ resulted in overwhelmingly positive responses. In most cases, learning was seen as related to the fact that monoclonal antibodies represented such a new area for AZ, e.g. "*The scientists learnt a huge amount because it was such a new area*".

Despite the fact that MAbs represented a new area, which AZ sought to access through the collaboration, a Senior Manager in R&D, on the other hand, emphasised that there were "*an awful lot of similarities in how you develop a cancer [drug] either with a small molecule or an antibody*". As illustrated by both the quotes, the Senior Manager saw

learning as a result of the process of working rather than "*something they set out to do*" and by working closely together on so many different targets, the scientists learnt "*the sort of thinking you need to put in place to select the biological targets*[...] *the sort of things you need to think about when you're developing an antibody through a target, as well as the differences between developing a cancer [drug] with an antibody as opposed to small molecules*".

In terms of the perceived learning, due to the similarities in small molecules and MAbs, the Senior Manager turned the focus on the development teams. By pointing to AZ's lack of expertise in development, which was emphasised in the section 6.4.1 above, the Senior Manager claimed that the learning was even greater for the development teams than for the research groups. This is illustrated in the quote below.

"Learning was being transferred all the time because obviously we were working very closely with them[...] on: what are the sort of thinking you need to put in place to select the biological targets? What are the sort of things you need to think about when you're developing an antibody through a target? Obviously we got a lot of learning out of just running that many targets. You know, we were effectively starting a new project once a month, so a lot of learning! But it wasn't really something we set out to do".

"Maybe there was more learning going on for the development folk, for the sort of development type activity [and specifically] manufacturing [...] I think there was a lot of learning going on between the development teams where they were meeting frequently as well and obviously planning how they were taking the first products forward. Obviously that came to fruition, but there was a lot of learning going on at that side and there was learning going on in the research and discovery side. But, as I say, a bit more specific because [...] how you develop a cancer either small molecule or an antibody, there is an

awful lot of similarities. There are some differences as well and it was important picking up what they were [in] these 36 projects and learning through that process".

A further interview with a scientist revealed that although he, through the collaboration, had learnt the more practical issues in how to develop MAbs, he had also increased his understanding and his scientific knowledge in several areas.

"Yes, there was learning going on, both I would say, of the process of developing the drugs as well as the more underlying science".

Interestingly, a Senior Manager claimed that the learning the biologics group obtained was clearly to be attributed to the scale of the collaboration, claiming that the same amount of learning would not be obtainable with a smaller scale, even if they had carried out several small scale collaborations, as illustrated in the following quote. This particular finding provides supporting evidence for one of the key findings in the cross case interviews, emphasising the importance of large scale collaborations for achieving learning.

"Could we have done it with a smaller scale collaboration? I think we could have got some learning from a smaller scale collaboration but nothing like we got. I think that if we had done a much smaller scale quite focused collaboration, we would have gotten some success, but we wouldn't have got the amount of learning that we got. I think it was the scale, which is to some degree set up like that. We felt we were behind the competition and we needed to do something fairly substantial to try to catch up quickly and I don't think that 4-5 target deal would have done that. We just wouldn't have... and then do 4-5 targets with someone else. I think actually upon reflection what we did was probably the right thing to do, have a really big collaboration with one partner".

Interestingly, however, when inquiring into the extent to which the biologics group actively sought to assimilate the knowledge throughout the Oncology group with a further Senior Manager, the interview revealed that this was not a formal goal, as illustrated in the following quote:

"We did not seek to spread what we learnt outside the collaboration. No, no, this was not a formal goal of the collaboration".

- Building innovative capabilities

In order to gain an understanding of the depth of the learning that AZ had acquired through the collaboration, the interviewees were asked if and to what extent the oncology therapy area had initiated further projects on the basis of what they had learnt (through the collaboration). Interestingly, inquiring into this matter with several Senior Managers and scientists, the typical answers were *"it happens all the time"* or *"It's a different world now, because we have MedImmune now. So, have we started new projects on the basis of that? [...] I don't know"*. (Senior Manager, Alliance Management).

Inquiring specifically into the effects of the subsequent acquisitions of CAT and MedImmune, several admitted that it is the former CAT that actually produces the MAbs and initiates new projects in MAbs. Although the latter suggested that AZ has acquired a capability in MAbs through acquiring CAT rather than through its collaborations with either Abgenix or CAT, this was further supported by a Senior Manager in R&D, revealing that initiating new projects on the basis of what AZ had learnt in the collaboration had not been a formal goal for AZ. This seems to be congruent with the above-mentioned finding, i.e. there was no formal goal of assimilating the new knowledge throughout AZ.

CAT

- Targets and effectiveness

Interestingly, an interview with a Senior Manager in CAT revealed that the initial targets (i.e. 25 over 5 years) had been reduced as the collaboration was initiated, as some of the targets were regarded as 'unrealistic'. Although there was a general understanding that the CAT collaboration had managed to reach most of the new set targets, several interviewees pointed out that CAT was acquired by AZ two years into the collaborations and as CAT had started to work with new therapy areas *"things had changed"* (more information about this in section 6.5.2). However, all the interviewees highlighted that AZ would not have been able to reach the same number of targets alone and the fact that AZ acquired CAT is the best evidence for an effective collaboration.

- Perceived learning

In the same way as the Abgenix collaboration, the CAT collaboration was seen to have contributed positively to learning. Whilst some interviewees were more modest in their answers, e.g. *"CAT started off just as a collaboration in a specific area around R&I – a working relationship that developed and improved our understanding of the whole area of monoclonals"*, others again claimed that the learning that was obtained through the collaboration had been *"revolutionary within AZ"*.

Interestingly, inquiring into why staff at AZ would characterise the collaboration as 'revolutionary' with a Senior Manager at CAT, the answer did not at all mention 'learning' but rather that the collaboration brought new and revolutionary opportunities for them as well as how the opportunities revolutionized the way projects were managed, as illustrated below:

"I think it was revolutionary because [of] the area of drugs they were working with and they respected our expertise in those areas. And they also [gave us] access to a whole new set of opportunities, so it was revolutionary [in terms of] the opportunities they could go for. There were bigger opportunities [...] with relatively fewer safety issues. It is revolutionary in terms of the types of diseases and the types of indications and the disease areas the overall organization could go for. They also revolutionized the way they thought of having management projects, try to stream-line things."

However, when inquiring explicitly into the extent to which AZ had learnt from CAT, the same Senior Manager stated: *"We all did in my view, we learnt very well from each other"*, showing that the learning interestingly took place both at AZ and CAT.

- Building innovative capabilities

In the same way as the Abgenix collaboration, when inquiring into the extent to which AZ had initiated new projects on the basis of what they had learnt through the CAT collaboration, the interviewees pointed to the fact that CAT was acquired and has ever since been responsible for initiating new projects in MAbs and producing them. Although this must be regarded as a logical step as AZ chose to acquire CAT, it enhances the suspicion that AZ acquired the capability in MAbs through acquiring CAT rather than collaborating with it. On the other hand, the fact that CAT still initiates new projects in MAbs is taken as evidence that CAT managed to keep its employees after the acquisition and, as such, kept its capability to innovate.

6.5.2 Effects of acquisitions and the underpinning reasons for AZ acquiring CAT and MedImmune

As mentioned in the introduction to this chapter (i.e. section 6.1), the inquiry into the implications Amgen's acquisition of Abgenix (i.e. in 2005) had for AZ and into the underlying reasons for AZ acquiring CAT and MedImmune, respectively in 2006 and 2007, provides a deeper understanding of the actual effects of Abgenix and CAT. Whilst this section firstly seeks to provide a deep insight into the effects and reasons for the acquisitions, it then seeks to provide insight into the new structure found in AZ after acquiring CAT and MedImmune, as well as an overall evaluation of AZ's extensive collaboration and acquisition strategy for entering into biologics as a company.

- Amgen acquires Abgenix

Two years into the collaboration between AZ and Abgenix, one of the world's biggest biotechnology firms, Amgen, acquired Abgenix. According to a Senior Manager, the major reason for Amgen acquiring Abgenix was that one of Abgenix's and Amgen's partnering products had become a registered drug. Besides the fact that this particular drug had been used as evidence for Abgenix's expertise when AZ was evaluating Abgenix's expertise in the first place (see section 6.3), the finding that Amgen acquired Abgenix subsequent to the launch of these products, illustrates a finding in chapter 5, i.e. big pharma firms actively seek to buy small firms with late stage products to secure their income stream.

"Now, a couple of years into the project because the EDFR antibody was about to make it to market, Amgen were their partner for that, obviously one of our main competitors, Amgen decided to acquire Abgenix". (Senior Manager, R&D, AZ)

An interview with a Senior Manager in R&D at AZ revealed that the most important outcomes following the acquisition by Amgen were: i) the activities related to the

collaboration were ring fenced and moved from Abgenix's San Fransisco site to its Vancouver site and ii) AZ aborted the development activity with Abgenix, see quotes A and B below. Whilst the first outcome came as a result of AZ's negotiations with Amgen and was a measure to prevent Amgen from obtaining insight into the activities involved in the collaboration, the second outcome was a result of internal discussions, building on a general understanding that *"it was not appropriate to develop stuff with a direct competitor"*. Referring to the fact that AZ had no knowledge in developing biologics, aborting the development activities was a major decision and was, as illustrated in quote b, the key reason *"that drove AZ to acquire CAT"*. Given the finding that CAT was considered to have only a modest capability in manufacturing (see section 6.4.1), acquiring CAT seemed more a desperate move to patch the capability in development. On another note, the fact that the loss of manufacturing capability that drove AZ to acquire CAT seems to undermine a previous finding that it was the development teams that had learnt the most through the Abgenix collaboration, illustrating instead that the development teams had not learnt enough to take responsibility for the development.

As illustrated in quotes C and B below, as one would expect, some interviewees felt that the acquisition changed AZ's relationship with Amgen significantly and that the collaboration became more arm's length (see quote C below), others, on the other hand, felt that although the acquisition "*added some complexity and obviously some nervousness about how it would go, it has actually gone very well because we had built up a very strong collaboration [...]"* (see quote A below)

"Because we had this exclusive deal, we had quite a number of discussions with Amgen about how to sort it out and in the end they sort of ring fenced the activity at the Abgenix's site up in Vancouver. So effectively, they were moving a lot of their sites up there anyway so effectively they sort of moved all our projects up to Vancouver site, where they had

expertise anyway still with the mice and we run our project over there, I guess, initially we were probably taking 80% of the resource of the Vancouver[site] [...]. Now we have a few projects left [...] at that site even today but we're finishing off so that's carried on for 3-4 years in that sort of working with Amgen but having put some sort of ring fences around the information so Amgen obviously don't get insight into us as a competitor. That obviously added some complexity and obviously some nervousness about how it would go, but it has actually gone very well because we had built up a very strong collaboration in the first two and a half years before the Amgen acquisition. So, people were keen to work with us, we were a good partner, and we were motivated to maintain that interaction". (Quote A)

"Because we were planning still before the Amgen acquisition to actually [have] Abgenix help us with the development activity, that is one thing that did die with the Amgen acquisition. We [...] obviously didn't feel that it was appropriate to develop stuff with a direct competitor, so we had to fish that out and as a consequence of that, really that drove us on to acquire CAT". (Quote B)

"It changed significantly when Amgen bought Abgenix and so, you know, it came out a little bit more difficult for us working with them. I think the relationship became a little more arm's length. But [it is] also [because of] the point when the program had come to us and what we did was to renegotiate the agreement with Amgen, and moved that forward, so essentially we could control much earlier". (Quote C)

- AZ acquires CAT

AZ took the strategic decision to acquire CAT in 2006. Despite a clear indication that the acquisition of CAT was motivated by the need to replace the loss of access to

manufacturing, the specific reasons for acquiring CAT were further investigated with Senior Managers both in R&D and Alliance Management.

Interestingly, a Senior Manager in R&D provided insight into the process leading up to the decision to acquire CAT, which involved discussions whether AZ should counter bid for Abgenix, stating that AZ wanted both *"to secure a [...] platform for developing antibodies and to maintain that later developing expertise"*. Other Senior Managers emphasised the importance of obtaining a "*discovery base in biologics"*, as illustrated in quotes E and F below.

"You have to reflect that we lost the manufacturing expertise and [...] as a consequence of Amgen taking over Abgenix we took a decision a year or so after that, to acquire CAT. Although we were having discussions what it would mean for us, should we even counter bid for Abgenix or should we think about accelerating our thoughts on the CAT acquisition. It took a little while to take a final decision about acquiring CAT but I think it was inevitability after that because we wanted to secure a delivery platform for developing antibodies and we also wanted to maintain that later developing expertise. CAT were like us using contract manufacturers for the large scale manufacturing; [them having] small scale manufacturing capabilities." (Quote D)

"CAT was bought for very clear strategic reasons, we wanted to have a discovery base in biologics, monoclonal antibodies, that we did not have. We wanted it to be competitive and we wanted it to be one of the major two or three platform companies in the world that had the best ways of discovering monoclonal antibodies from huge libraries" (Quote E)

"That was the time when Abgenix had been bought by Amgen and [by aquiring CAT] we bought a discovery base in order to flow project ideas into that discovery base to generate

a whole flow of antibodies and [...] provided that that migrates beyond antibodies to other biologics. So that's quite different from going to CAT and saying we would like collaborate on this one project on arthritis with you, because we've got excellent animal models and excellent clinical expertise or whatever". (Quote F)

Interestingly, the rationales for acquiring CAT, i.e. *"to secure a delivery platform for developing antibodies", "to maintain that later developing expertise"* and *"we wanted to have a discovery base in biologics, monoclonal antibodies, that we did not have"* all seem to suggest that the CAT collaboration alone was not sufficient to build innovative capabilities, neither in discovery nor in development. Hence, AZ could only gain these capabilities by acquiring CAT. Quote F also seems to suggest that only by acquiring CAT would there be a sufficient flow of *"a whole flow of antibodies [...] that migrate beyond antibodies to other biologics".* The latter is particularly interesting as there was no aim to assimilate the knowledge obtained through the collaborations outside the collaboration (see section 6.5).

On the basis of the above, it seems reasonable to conclude that despite AZ's efforts at forming large scale collaborations, these collaborations alone were not sufficient for AZ to build innovative capabilities in MAbs. On another note, although one of the reasons for acquiring CAT was *"to maintain that later developing expertise [i.e. manufacturing expertise]"* (see quote D), CAT only had a modest capability in development and then only early stage manufacturing expertise and, as such, CAT could not replace the loss of the manufacturing expertise which AZ originally had accessed through the Abgenix collaboration. As will be discussed below, AZ's need to obtain a capability in late stage development was the key driver for what would be AZ's next acquisition, of MedImmune.

- AZ acquires MedImmune

A year after acquiring CAT (i.e 2007), AZ carried out the acquisition of MedImmune. MedImmune was at that time one of the biggest vertically integrated biotech firms.

As seen in chapter four, AZ acquired MedImmune for $15.2bn, a price that resulted from competitive bidding and which, according to Sahoo (2008), set 'a new high for pharma-biotech acquisitions' (p. 43). According to Sahoo, 'the all-cash purchase price of acquisition represents 63 times the midpoint of the company's earnings and about 10 times its revenues' (p. 43), whose annualised 2007 value was just in excess of $1.4bn. Interestingly, a large part of the price represented the value that AZ attached to MedImmune's knowledge and expertise, which are not reported in MedImmune's accounts but now appear in AZ's balance sheet in the form of intangible assets at fair value and goodwill.

Inquiring with Senior Managers across AZ into the reasons for buying MedImmune, it appeared that although MedImmune had strong capability in vaccines, it was the company's capability for developing biologics and bringing biologics to the market that drove its decision. The quote illustrates the need to gain the latter capability quickly as "*the pipeline of biologics were filling*".

"It was a much broader base thing that led to the purchase of MedImmune. [We] wanted the other skills much more quickly because the pipeline of biologics were filling in that [gap of] regulatory, clinical [set of skills] we needed [...] to take biologic through the regulators. And we needed it quickly! We didn't want to build it. The other alternative was to build it organically and keep investing, and so the company was in a very strong cash position. And, indeed, in the time before the credit crunch, there was very strong advice that you could afford to have some debt on your balance sheet, then it gave us the ability to

buy and create fully integrated pharmaceutical activity all the way through from target through to launch of products on the market place. If you like, we matured into a pharmaceutical capacity from cradle to grave within the space of six months instead of six years".

When inquiring explicitly into whether the major reason for acquiring Medimmune was to have a capability in the late stage development, this was confirmed by a Senior Manager in AZ. As illustrated in the following quote from this Senior Manager, CAT's early stage manufacturing did not make up for the loss of Abgenix's expertise and this is what drove AZ to acquire MedImmune.

"Then you have to reflect that we lost the manufacturing expertise and although we acquired [CAT], CAT didn't really have the vast scale expertise and that's what we acquired in the next step on with Medimmune. Abgenix had their own manufacturing. Obviously we weren't going to acquire that expertise through them. CAT has some expertise in that area but it was more sort of early stage manufacturing, and Medimmune had the late stage function, manufacturing capability and expertise and knowledge so that's why Medimmune was a logical step after CAT. As a consequence you also got a lot of biological expertise as well but I guess at the time with the Abgenix and the CAT deal we were not quite thinking as big as acquiring someone like Medimmune. But obviously [these successful] collaborations built the need to accelerate our biologics further".

In sum, the investigation into the implications of Amgen acquiring Abgenix and the subsequent reasons for AZ acquiring CAT and MedImmune shows that AZ lost manufacturing capability when Amgen acquired Abgenix. Also, although AZ sought to secure both discovery and manufacturing capability, which in itself gives the ultimate evidence that the Abgenix and CAT collaborations had a limited impact on AZ's capability

building, the latter was considered particularly important for acquiring CAT. CAT, on the other hand, had a capability in small scale manufacturing and given that AZ had already invested large sums in CAT and Abgenix but still had no large-scale manufacturing capability, AZ had little choice but to pay over-the-odds for MedImmune.

- The new structure of AZ

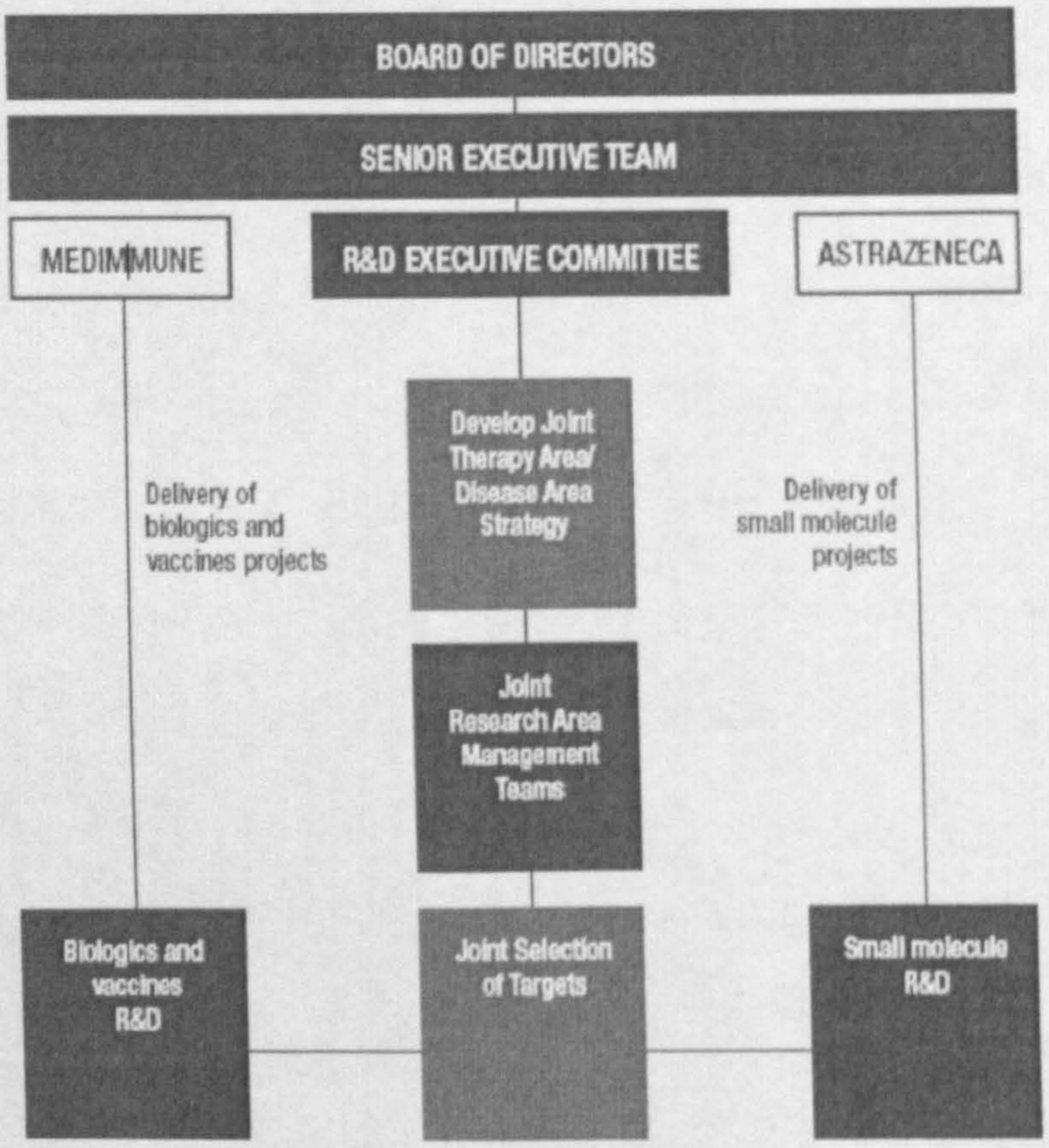
Having achieved a defined position in biologics when acquiring MedImmune, AstraZeneca unveiled, in December 2007, a new strategic operating unit, i.e. Global Biologics Organization (GBO) centred round MedImmune. The GBO consolidates biologics capabilities from MedImmune, CAT and AZ's own research and development group. "Incorporating these three previously distinct groups, the GBO has end-to-end capabilities from discovery through to commercialization in several key therapeutic areas including infectious diseases (monoclonal antibodies and vaccines), respiratory and inflammatory diseases, central nervous system disorders, gastrointestinal conditions, cardiovascular disease and oncology. This includes high-productivity antibody platforms, high yield purification processes, and proven scale-up capabilities for a diverse production portfolio" (Sahoo, 2008, p. 115).

It is interesting to note that, with the formation of GBO, AZ shifted the work in research biologics under the management of MedImmune, enabling AZ to focus on small molecules, reflecting its heritage (see quote by CEO, section 6.2), as illustrated in the figure below. Despite the separate responsibilities, the figure shows that there are joint research area management teams. The extract below, taken from an interview with a Senior Manager in Alliance Management provides a deeper insight into the joint area management teams, showing that they primarily operate in the areas of oncology and R&I, which interestingly are the areas in which the Abgenix and CAT collaborations respectively were

formed. The extract also shows that a joint research committee is necessary in order to ensure that the two old AZ and GBO seek to reach the same targets.

Figure 6.1

Figure 6.1 provides an illustration of AZ's new company structure:



(Source: AZ 2007 Annual report)

The extract below is taken from an interview with a Senior Manager in Alliance Management, where 'I' stands for Interviewee and 'R' for Researcher.

I: We have a joint research committee, it's working two therapy areas where biologics are more relevant, i.e. oncology and RI. What you have of joint management is that, basically in the research they discuss what are the best targets to go for your internal programmes, antibody or a small molecule, which ones are the best and, at the later stage, it is jointly working through the development.

R: So this is working, although they are different approaches?

I: Yeah, it is obviously important that we do it jointly, that we don't find ourselves inadvertently chasing the same target with a small molecule and an antibody and we don't know that and repeating [activities]. But we [know] equally well [how important it is] that the business development folks talk to each other, so they don't go and we don't go and license something in for the same target.

The latter statement hints at separate Alliance Management offices. The 2007 annual report confirms this, holding that "all of our biologics and vaccines externalisation activities will be led by MedImmune". This particular finding seems to provide the ultimate evidence for the finding that only by having relevant knowledge will firms be able to evaluate the potential of candidate collaborators.

The finding that AZ obtained a defined position in biologics with its acquisition of MedImmune is illustrated in its 2007 annual report, as illustrated in the following.

"The acquisition of US based biotechnology company, MedImmune, Inc., in mid-2007 has enabled us to greatly accelerate our biologics and vaccines strategy and build on the expertise of Cambridge Antibody Technology plc (CAT) acquired in 2006 and pre-existing biological programmes. It has also enabled us to create a significant, world class vertically integrated biologics and vaccines capability through which we have access to cutting-edge technologies, intellectual property, a skilled and dedicated workforce and large scale manufacturing capability. All of our biologics and vaccines capabilities will be operated under MedImmune's leadership" (p. 25).

- Effects of collaborations and acquisitions

When inquiring into the total effects of the recent collaboration and acquisition strategy with several interviewees, the answers illustrate not only that this activity has increased the overall portfolio by 25% but that there has been a transfer of the use of MAbs from Oncology and R&I to Metabolic disease and Neuroscience. It is important to note that AZ actively set up internal collaborations between CAT and these new therapy areas, which were not traditionally associated with MAbs. This lay at the heart of AZ's broader strategy, i.e. applying MAbs to new areas.

Though the first quote below illustrates that there has been a knowledge transfer from Oncology and R&I to metabolic disease and neuroscience, the quote seems not to provide an accurate insight into the extent to which this was a result of both collaboration and acquisitions or only collaborations. Inquiring deeper into this with a Senior Manager at CAT, the manager confirms that work in metabolic disease and neuroscience only started after CAT was acquired. This finding seems to be in line with previous findings, holding not only that there was no formal aim of assimilating the knowledge obtained through the collaboration throughout the associated therapy areas, let alone between the various therapy areas. On the other hand, it is interesting to note that the Senior Manager in R&D states that metabolic disease and neuroscience had less expertise in MAbs than Oncology and R&I as they had not been in collaboration with CAT or Abgenix. This seems to confirm that although the collaborations had limited effects on capability building, learning was evident in the groups that were involved in the collaborations.

"Inside the biopharmaceutical portfolio, there are mainly cancer, oncology and respiratory and inflammation drugs in the portfolio but there are also vaccines, which MedImmune brought in. And there is now quite a healthy number of projects coming from metabolic disease and neuroscience, because those therapy areas have now got access to

that technology platform and there's things coming along in those therapy areas. So, in the end, biopharmaceuticals will spread out from, if you like, oncology and respiratory and inflammation, when they started collaboratively, because we bought CAT into a much broader base, and in fact, very exciting of course because if you look at the market, antibodies are particularly strong and incredibly competitive now in oncology. Chemira [for instance] has shown the way of how antibodies can be used to treat something like Inflammatory disease and so, to some extent, the biopharmaceutical world portfolio with all the competitors in that is very rich in those areas, whereas this work [Chemira] has been done in the other therapy areas there's considerably opportunity. We believe that metabolic disease, neurologic disease and so on, for biologics look very promising and indeed it is the therapy area focus to drive into those areas which potentially have got some breakthroughs and they're less competitive so that's part of the strategy coming off in my view".

"So... the alliance was in the R&I area, they then acquired CAT which then allowed us to work more collaboratively with Oncology and then they acquired MedImmune and CAT got integrated into MedImmune, and then they brought in the option to start working more with neuroscience and cardiovascular, which were the areas in AZ which [were] maybe less advanced in their biologics portfolio, because they hadn't been in alliance with CAT or an alliance with Abgenix, so it has been a gradual bringing on board the different therapy areas within AZ starting with R&I and now we are trying to work very proactively with neuroscience and cardiovascular, and I think we've learnt quite a lot through what we've been through. So, I am hoping that in the cardiovascular area we can come up with even more innovative ideas for those areas. We've also brought in some new technology, which allows us not only to work with antibodies but with peptides and various types of peptide drugs, which potentially are very applicable in metabolic diseases. There are more opportunities to do the technical side of things as well.

An interview with another Senior Manager at AZ provides not only the insight that the collaboration and acquisition activity has increased the development portfolio by 25% in four years, but that the process has been significantly more efficient. According to this Manager, such results justify spending $15 bn on MedImmune alone (see quote below):

"If you say that we had no biopharmaceuticals in our portfolio at all, by 2010 we hope to have 25% of our development portfolio as antibody and other biological opportunities. You could say that those have all come from M&A and collaborative activity; collaborative activity with Amgen in cancer, collaboration and then M&A with CAT in respiratory and inflammation and all the MedImmune compounds, as well, and we will easily get that 25% by 2010. If you compare that to 2006, when we only had collaborations, we hadn't acquired these collaborations; we acquired CAT in 2006, then in four years, we would have inserted 25% of our portfolio through that activity. So, that kind of begins to approach that question of how you justify investing $15 bn. Well you certainly justify it by transforming the pipeline by 25%, and indeed if you do the maths on how many people in the R&D organisation will be in biologics organisation supporting this 25%, this will actually be a lot less and a much more efficient process. It is a transformative step, it's risky and it may not come off but, you know, you won't survive if you don't take some risks". (Senior Manager, AstraZeneca)

- Collaborations as intermediary steps towards acquisitions

As a last point on the effects of collaborations, although the above to some extent illustrates that it was the lack of development expertise that drove the AZ decision to acquire MedImmune, the next quotes illustrate the importance of the role the collaborations played for AZ before it committed fully to the acquisition of MedImmune.

The first quote is a reflection on how AZ had interacted with several sources to obtain a capability in biologics: *"Buy or build? Build that sort of [skills]? It would have taken us much longer to build them internally. Equally well, to jump straight into a MedImmune relationship and bought a big company? We decided not to do that, but to put a toe in the water first. So, what we did was to enter a major collaboration, then CAT and we liked that so much that we fully committed to completion".*

The second quote illustrates that although AZ probably would have acquired MedImmune regardless of the acquisition of CAT, the knowledge obtained from CAT put AZ in a better position when acquiring MedImmune.

"CAT represented a real opportunity for acquisition, so that was taken forward. I suppose if the question is if the MedImmune acquisition hadn't happened, had we not acquired CAT? I don't think, personally, we would have done that, but certainly, there's no doubt that the expertise and knowledge that we gained with CAT enabled us to do a better job with the MedImmune acquisition". (Senior Manager, AZ)

6.6 Success factors

With both collaborations reaching the set target as well as AZ acquiring knowledge from its partners, the Abgenix and the CAT collaborations were regarded as *"highly successful"*. This section seeks to present the key factors for collaborative success behind the respective collaborations.

Abgenix

"Enthusiasm" was the immediate response when inquiring into the key success factors with the lead scientist of the collaboration. The Senior Manager continued, saying, *"You*

know, the time we started it, it was major to us, it was a whole new area at AZ so there was a lot of enthusiasm to make it work, enthusiasm for the people involved to make it happen".

The way to enthuse and commit Abgenix was to involve them right at the start by, quite unusually, according to a Senior Manager in R&D, involving them in selecting the targets that would go into the collaboration. Involvement was further ensured at every step of the process of the collaborations, e.g. there was joint leadership for every project (confirming point in section 6.4.2) and joint managerial groups, both for research and development.

Interestingly, whilst joint representations at the various levels *"was crucial for the efficient running of the projects"*, the fact that Abgenix was involved in the selection of targets was seen as particularly important for the level of commitment AZ got from Abgenix. As illustrated in the quote below, thanks to being involved by AZ in the process of target selection, Abgenix not only *"wanted to work on our projects"* but felt *"committed to deliver"*. Paradoxically, whilst the quote, by the Senior Manager, gives the impression that the way AZ involved Abgenix in the selection as targets was 'unusual', he recognised that treating Abgenix as a contract research organisation, hired to work on a set number of targets, would have had *"a very different outcome"*.

The lead scientist further emphasised that thanks to AZ's success in inspiring a collaborative spirit, enthusiasm and commitment from the start, the firms *"weren't working as two firms but almost as a single group"*. Several other interviews highlighted the same point, as illustrated in the following quote: *"I think there was real enthusiasm on both sides to want to really deliver it"*.

The quote below illustrates most of the insight shared above:

"I think for the start we generated a very strong collaborative spirit of where to go. I think, with Abgenix and clearly the comment we got from [those involved in] Abgenix was we were the best collaborators and we got them involved in the project much more than their other collaborators they had worked with. I think it was about Abgenix wanting to work on our projects [that made it a success]. I think it was that we made them feel we were working as a single group. Although they were another company, we were AZ oncology biologicals and we were trying to work as a joined- up group, with them feeling commitment to wanting to deliver. I think that's what [made] it a success is that people, everyone, on both sides, was really committed to wanting to deliver, because we weren't using them as a contract research organisation. There was a really true collaboration; as I said, we involved them at every step, we didn't just say 'do you want to work on these targets?' We involved them in the whole process by which targets we should work on. They were motivated by the start of deciding the targets and their involvement of helping in selecting. We could just have gone in and said 'people work on these ten targets that we've decided we want to work on' [but] I think [this] would have had a very different outcome and we really tried to make it a joined up process from the earlier stages."

Interestingly, whilst the lead scientist in particular highlighted the importance of ensuring commitment and enthusiasm, other interviewees pointed at the importance of the firms having complementary skills. The latter is particularly interesting as the deal structure seemed to suggest that Abgenix did most of the work. When inquiring more into this, a Senior Manager in R&D pointed out that AZ had effectively contributed to collaborations with its preclinical models and commercialisation, pointing out that drug innovation involves more capabilities than discovery and manufacturing. In the end, the Senior Manager claimed that the complementarities of skills created mutual benefits for the firms involved in collaboration, as illustrated below:

"Together [this brought] mutual benefits. So they had antibody generation technology to meet and peak through the early research stage, to produce antibodies, including cancer. We didn't have that. We had sort of later stage stuff of models, preclinical models, which leads to development and then we would commercialise the products".

CAT

When asked about the key factors behind the CAT collaboration, a Senior Manager in R&D, pointed directly to the fact that AZ, on the one hand, had demanded a large scale collaboration with CAT and that CAT, on the other hand, required to act as a competitor of AZ in oncology at the negotiation stage (see section 6.4.2). By doing so, the partners managed to *"quantify the scope of the collaboration [as well as] express their mutual aspirations at an early stage [...] providing a basis for the collaboration".*

Interestingly, the importance of formulating common goals was further emphasised by a Senior Manager at CAT. However, rather than overall aspirations and scope for the collaborations, this Senior Manager stressed the importance of formulating common goals, both for the collaborations in general as well as for the drugs. As seen in the quote below, whilst the goals for the collaborations included the number of drug candidates, how many projects they would initiate and the attrition rate, the goals regarding the drugs indicated the desired characteristic of the drug candidates. Interestingly, the quote below shows that the formulation of the drug goals involved not only scientists but employees from all the stages of the product development, e.g. R&D, clinical development, regulatory, commercial.

"Having very, very clear goals, based around the number of drug candidates we were aiming to deliver by when, having a very clear view of yeah we're going to do this many

projects, the attrition rate we're expecting, we're going to deliver this many projects to deliver drugs so many candidate drugs, and really think of decisions, make joint decisions and stick to them, and then go off doing an additional piece of work. The project teams [approach was to] keep focused, make sure that you initiate a project when you say you will and that the project is mapped out, you deliver what you say that you're going to deliver. Having had several partners before, we knew how to deliver antibody candidates. And the other really important piece is to make sure we defined what we wanted from those drug candidates. So, we had a very good kick off conversation, not just with people in the research, but with people clinical, regulatory, commercial. Now will an antibody do this? What kind of characteristics they needed to have? Did we want them to bind to humans and mouse?"

A further success factor was to operationalise goals in a matrix, setting out a time frame for each of the projects and a careful planning of the actual projects. Interestingly, and according to this Senior Manager, quite unusually, planning also included what was expected from the managers when they *"behaved and interacted in respect to the project teams"*. As expected, the quote also emphasises the importance of keeping the schedule and that managers initiated the project according to plan.

"The only other thing that worked well is that we set very clear goals, a clear matrix of what we were trying to achieve and by when, and we did some very good planning, so we made sure we had an organization on the scale that could deliver the goals. We also were talking a lot about how we were going to behave [in special situations] and actually make sure a real joint decision making and as soon as the decisions were made we went out to support them and it was a very open dialogue of what was expected from us when we behaved and interacted in respect to the project teams, which was quite unusual, I think, and again very successful".

In addition to goals and planning, several interviewees highlighted the importance of having a supportive culture and complementary skills.

In terms of culture, a Senior Manager in R&D emphasised the importance of CAT and AZ being *"attuned to each other"*. It is interesting to note that an interview with a Senior Manager at CAT further revealed that AZ was very supportive of CAT's ideas and way of working, which she clearly saw as another key factor to the success of the collaboration (see quote below). Putting this finding together with a finding in the cross-sectional interviews, which holds arrogance on the part of big pharma firms as one of the factors that inhibits big-pharma-small-biotech collaborations, provides evidence that the way big pharma acts makes a difference for the success of a big-pharma-small-biotech collaboration.

"I think AZ was very, very careful. AZ understood that they were a big pharmaceutical company and they did have a level of, you could say, bureaucracy associated to a large company. They were very [aware] of this, when they came in the alliance with CAT. So what they didn't want to do was to force us to work in the same way they had been working in the small molecule area. They were very, very prepared to listen to us; what works for us for a small biotech, what made us innovative, what types of technologies we were prepared to bring in and how much we would invest in technology development. They listened and they didn't try and force us into their mold. They actually moved more to a way of working that would accommodate what we said we would work, which was revolutionary for them and I think that was very commendable of them, that they were prepared to really take that risk. I think that just the idea that it was the research committee that had decision making control and the project teams had some control at some level so people were empowered working in the alliance. I think it was revolutionary in that way."

Though recognising the importance of the factors above, a Senior Manager in CAT attributed the success of the collaboration to the fact that each of the firms knew what their skills were, pointing to AZ's understanding of commercial niches and methods to develop them and CAT's capability in the early research and producing antibodies. As such, this provides a clear illustration of Arora and Gambardella's idea that there is a division of innovative labour taking place between small biotech and big pharma firms.

"The real sort of reason the alliance was so successful was because, I think, both organisations really understood what their strengths were. So, we as an organisation realised that we as an organisation did not necessarily understand as fully as AZ the equal opportunities in the disease areas. How do you define the commercial niches that you want to work in? Because we had never really taken anything all the way through to the market as a stand alone company, we knew something about the early research and how you make good antibodies preceding the clinical trials. This is the clinical piece, we had a model were we did a lot of the early work in collaboration with the biologists, pharmacologists and gradually AZ [at] the later stage".

6.7 Key processes behind the knowledge transfer

As seen in chapter two, research question two aims at addressing the gap in the literature regarding the practice behind absorptive capacity. By adapting a theoretical framework of Zahra and George (2002), the research question sought to investigate the key processes by which a firm acquires new knowledge from a collaborator and then assimilates, transforms and exploits this knowledge.

The fact that AZ used two large scale collaborations to enter into a new area seemed to be an ideal context for the research question. However, as seen in section 6.5.1, the investigation showed that AZ ended up acquiring CAT and, as such, it is still CAT that produces MAbs. Whilst this excluded the possibility of investigating the key processes AZ used to exploit knowledge in MAbs, the fact that CAT was coupled with two further therapy areas, which are not traditionally associated with research in MAbs, provides an intriguing context to study the key processes which enable these therapy areas (i.e. Metabolic disease and Neuroscience) and CAT to transformed and exploited MAbs. Although the focus of the investigation was adapted, it still contributes to the overall aim of the research question, i.e. to provide a 'first' understanding of the practice behind absorptive capacity.

The different dimensions, i.e. acquisition, assimilation, transformation and exploitation of knowledge, will be presented in separate sections below. Importantly, given the important role the acquisition of CAT played in the assimilation of knowledge and the subsequent transformation and exploitations, the investigation will primarily focus on CAT.

6.7.1 Acquisition of knowledge

When initially asked about knowledge acquisition, several interviewees highlighted that acquisition of knowledge was a key reason for *"getting so deeply engaged with two external partners in the first place"*.

Interestingly, however, when inquiring into the key processes that enable AZ to acquire knowledge from its collaborators, the interviewees highlighted the importance of prior knowledge.

"Obviously we had some knowledge in the area, it would be crazy to think that we would be able to learn without any prior knowledge in the area".

To emphasise this point, one of the interviewees pointed to the fact that AZ had sought to initiate a couple of projects on their own in the past and that it was this, together with the growing importance of MAbs, that had *"pushed through the strategy of entering into MAbs"* (see also section 6.2). To further illustrate the importance of prior knowledge, the same interviewee pointed to the fact that the person responsible for AZ's early projects in MAbs had become the lead scientist in AZ's first collaboration, i.e. the Abgenix collaboration.

As the latter suggested that AZ had its own 'champion in the field' (which was highlighted as a key factor in the cross-case interviews, see chapter 5), the importance this played for the collaboration was investigated further. Interestingly, the interviews showed that the most senior employees in the field were put to manage the various projects. Given that there was joint leadership for every project (see section 6.4.2), this suggested that the projects were managed by 'champions on both sides of the collaboration'.

In terms of their impact, it is interesting to note that an in-depth interview with a scientist revealed that although he acquired a lot of knowledge about the process behind developing MAbs in the daily work, more scientific knowledge was acquired through the research review committees. According to the scientist, it was in these committees that the projects were reviewed scientifically. The scientists also frequently had to defend their ideas and their projects, which contributed to 'learning' (i.e. AZ acquiring knowledge).

The importance of the review committees was later confirmed by a Senior Manager , but the interview also revealed that the feeling of the two firms being 'joined up' positively contributed to the possibility of learning through the collaborations, as illustrated in the quote below.

"The consequence of feeling we were joined up together was [that]... there was openness in terms of people [being] prepared to say what they thought at the meetings and input learning from their end".

In terms of support, it is interesting to note that several interviewees highlighted the importance of databases. The interview revealed that AZ had set up a big database prior to the first collaboration with Abgenix. According to a Senior Manager, the purpose of the database was not only to store the relevant ideas related to the different projects, but to ensure an effective way of assimilating all relevant data regarding the projects between the collaborating firms. This latter was seen as particularly important for AZ, as most of the work was carried out at AZ. The database was regarded as being so successful that it was replicated not only to CAT but also to the small molecule activity. This supports the finding obtained in the cross case interviews that a successful collaboration requires an efficient system for transferring relevant data and information.

Interestingly, these findings obtained through the investigation into the processes that enable a firm to acquire knowledge, i.e. large scale collaborations, the importance of prior knowledge, champions on both sides of the collaboration, supporting environment and efficient system for data transfer, are directly in line with the factors held as key for circumstances needed for a collaboration to have an impact on capability building.

6.7.2 Assimilation

It is noteworthy that whilst acquiring knowledge was a pronounced strategy, there were no formal aims of assimilating the knowledge obtained through the collaborations outside the collaborations (as seen in 6.5.1). Inquiring further into this with a Senior Manager at AZ, it appeared that assimilation of new knowledge was not even encouraged in their respective departments, illustrating that there are few methods to assimilate knowledge in big pharma firms. Picking up on the finding that valuable knowledge is primarily assimilated informally, the investigation sought to understand the extent to which the new knowledge was assimilated through informal networks (see chapter 5). Interestingly, as a direct response to this inquiry, a Senior Manager stated: *"That's not significant! What is significant is that we made AZ collaborate, if you want, with Metabolic disease and Neuroscience [new therapy areas]"*.

The latter confirms a previous finding that internal collaborations were formed between the former CAT and the new therapy areas (see section 6.5.2); this was a clear element of AZ's broader strategy of seeking to innovate in new areas not traditionally associated with MAbs.

6.7.3 Transformation

Interestingly, in the same ways as in the cross-case interviews, the interviewees found it difficult to answer direct questions regarding 'transformation'. Reflecting upon the response, it seemed as if this terminology did not resemble the way scientists were working, e.g. were they transforming knowledge?

Focusing the discussion on the way that CAT was working in the new therapy areas, the interviews seem to suggest that as these were new areas, CAT seemed more dependent on input on the niches in the market and likewise the new therapy areas were more dependent on CAT's expertise on how these niches could be reached, using MAbs. As such, the case study illustrates the importance of the partners' distinctive capabilities.

6.7.4 Exploitation

In direct correspondence with the pilot study, several interviewees emphasised the importance of 'proof of concept' for exploitation. The underlying reasoning seemed to be that only by having a pre-set measure to evaluate the extent to which the candidate drug does what it is expected to do, are pharma or biotech firms able to take an informed decision of whether to exploit (i.e. develop) the candidate drug.

6.8 Summary

Given clear indications in the cross-case interviews that big pharma uses collaboration to enter into new areas, it is interesting that the case study shows that forming collaborations with two external firms was AZ's initial strategy when seeking to enter into MAbs and, more generally, biologics.

In terms of the effects of these collaborations, the case study appears to give an intriguing picture, i.e. whilst interviewees, on the one hand, claimed that they had learnt from the collaborators, the evidence of the implications of Amgen acquiring Abgenix and the subsequent reasons for AZ acquiring CAT and MedImmune, on the other hand, illustrates that the collaborations had a limited impact on AZ's capability building.

The finding that collaborations have limited impact is particularly interesting as the collaborations match the criteria set by the cross-case interviews, e.g. prior knowledge, champions on both sides of the collaboration and supporting culture.

As seen above, the investigation into the processes enabling the different dimensions shows that the above mentioned criteria only have an impact on knowledge acquisition rather than capability building.

Whilst the match of criteria might have contributed to the sense of learning, this finding seems to suggest that the collaborator's knowledge was too 'sticky' for the firm to build new capabilities in the new area. Stickiness will be returned to in chapter 7.

The case study further showed that there was no goal of assimilating knowledge outside the respective collaborations, i.e. assimilation of knowledge had only taken place after AZ had acquired CAT. The latter took place by CAT forming 'internal collaborations' with further therapy areas, seeking to use MAbs in new areas. Interestingly, transformation seems to depend on complementary capabilities, which in itself provides evidence for the notion that extramural knowledge plays a crucial role for innovation. Exploitation, on the other hand, requires pre-set measures to evaluate the potential of the candidate drug, i.e. what the industry calls 'proof of concept'.

The case study raises interesting insights into the effects of large scale collaborations as well as the processes under investigation, which will be examined in the next chapter.

Chapter 7:

Analysis and discussion

7.1 Introduction

The overall aim of the chapter is to analyse the key findings obtained through the investigation into the distinctive importance of R&D and collaborations for innovation and capability building (i.e. *research question one*) as well as the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge from a collaborator (i.e. *research question two*) and discuss them in light of the relevant literature. In order to provide the best basis for doing this, the chapter is structured around an intriguing set of findings obtained through the investigation of *research question one. These are that **despite the key role of R&D increasingly is becoming to identify collaborators, collaborations have limited impacts on capability building.*** Each of the findings is presented in distinctive sections, respectively in sections 7.2 and 7.3. Given that the investigation into the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge (i.e. *research question two*) provides a deeper understanding of the latter finding, the findings obtained through research question two will also be presented in section 7.3. The chapter ends with a concluding summary of the main theoretical contributions of the research, in section 7.4.

7.2 R&D and the importance of identifying and evaluating collaborators

In terms of the distinctive importance of R&D, the research reveals that the key role of big pharma's R&D is increasingly to identify and evaluate potential collaborators[19] and their discoveries, and to develop their candidate drugs. Confirmed by all interviewees in all the sample firms, including industry 'experts' (see section 5.2.8), the emphasis of this role reflects the increasing importance of the emerging new areas, e.g. biotechnology and genomics, and having failed to exploit this knowledge, big pharma has increasingly become dependent on forming collaborations with small biotech firms to 'reap the benefits' of their discoveries (5.2.1). Hence, forming collaborations with small biotechs allows big pharma to enter into the new areas (see section 5.2.2). The importance of biotechnology and genomics is illustrated in the following quotes from the CEO of AZ:

"Research has shifted to a somehow new arena. Products that are successful on today's market place are a result of research that took place between 1970 and 1990. While work in that area [of research] continues to some degree, it has been pretty well harvested and the new areas that have emerged [are] really biologics and genomics. We're working through [those] to figure out how to produce personalised medicine: a world of enormous promise for the future".

Despite increasingly seeking to gain new candidate drugs by collaborating with small biotech firms, big pharma is principally responsible for their later development, a finding further confirmed by most big pharma-small biotech collaborations (see section 5.2.3). The finding that collaboration increasingly is becoming the key means to gain new candidate drugs and that big pharma is carrying out development illustrates, though the research is based on a sample of just three big pharma firms, that a 'division of innovative labour' is

[19] This formulation of the role reflects both the importance of identifying and evaluating compounds (as emphasised in section 5.2.8) as well as the importance of identifying and evaluating collaborators (as emphasised in section 5.3.1). In both cases is big pharma responsible for the latter development.

taking place in the pharmaceutical industry (Arora and Gambardella, 1994). As seen in chapter two, it is interesting to note that the possibility to separate the various sub-tasks within innovation processes is caused by the rise of general and abstract knowledge, allowing the distinctive players to focus on tasks where they have their strongest capabilities, i.e. small firms focusing on the former stages of drug development and big pharma on the later stages. Directly in line with Nooteboom, 2005, interviewees from big pharma emphasised that is the low level of bureaucracy found in small firms that enables them to carry out novel and riskier innovation projects. On the other hand, whilst innovation in big pharma was seen to inhibit big pharma innovation (see section 5.2.7), the interviewees interestingly emphasised that the scope of the science and technology needed in the different therapy areas as too large for these large firms to remain competitive (see section 5.2.1). Meanwhile, interviewees from outside big pharma (i.e. Consultants, Professors) identified late entry into biotechnology (and hence a lag in technology), the employment of overly similar people, and risk adversity as key factors for big pharma's R&D having failed in the recent years. Whilst the large firms are more capable of carrying out large scale development, production and marketing, as these capabilities are seen as being more reliant on slow, evolutionary processes (Arora and Gambardella, 1990b), it is interesting to note that this research finds clear indications that small firms seek to learn about development from big pharma (see section 5.2.5).

Given that the new role of R&D is seen as a direct result of: i) the increasing importance of collaborations with smaller biotech firms over big pharma firms' own R&D for obtaining new candidate drugs and ii) the fact that collaborations are organised in such a way that big pharma is responsible for carrying out the later stages of the development of this knowledge, this research argues that the shift of focus in big pharma R&D is a result of a 'division of innovative labour' taking place in the industry in recent years. Although Kneller (2003) has argued that the role of the R&D function of large pharmaceutical

companies is gradually changing from one where the basis for drug development follows from an in-house R&D model, to one that builds on external acquisitions of innovations from universities and biotechnology firms, this research provides exact insight into what this new role consists of. In light of the exponential number of small biotech firms that have emerged since the introduction of biotechnology (see chapter one), the new role of big pharma R&D seems to be to identify the most promising collaborators.

Interestingly, although actively using collaborations as a means to obtain new drugs, most big pharma firms find themselves in a situation where they face patent expiries on many of their key products. This is illustrated the following quote made by a Senior Manager in Alliance Management: '[...] *the industry is in a period of contraction and in approximately four years will see a further >$120 billion loss of patented products. Even if the smaller companies were swallowed at zero cost by the larger companies the pipelines of these smaller companies would leave a gap of $80 billion in revenue*'. Given the urgency of big pharma's need to replace these drugs, several senior managers stress that the ability to identify, evaluate and develop externally invented candidate drugs will be of even greater importance in the future.

The remainder of this section seeks firstly to provide a deeper understanding of the new key role of R&D, by drawing on various innovation measures (section 7.2.1). It then seeks to evaluate this new role and 'its requirements' in light of the absorptive capacity literature (section 7.2.2). By doing the latter, the research proves to have clear implications for the division of labour and, more generally, the complementarity literature.

7.2.1 Evidence for the increasing importance of collaborations

As seen above, the core of the argument is that the new role of R&D is a direct result of the increasing reliance on collaborations for obtaining new candidate drugs. This change is supported by the investigation into the origins of the drugs as well as the number of patents, carried out as part of archival analysis on the sample firms, as summarised below.

As seen in chapter four, the investigation into the origins of the drugs sought not only to compare the current number of products stemming from the sample firms' R&D, collaborations and M&As but also to calculate their respective economic value[20]. The results obtained for Pfizer, GSK and AZ are summarised below.

- Pfizer

Although the document analysis, as a starting point, shows that the number of drugs obtained from R&D, collaborations and M&As are similar[21], the number of drugs obtained through collaborations accounted for 59% of all revenues in 2007. The high proportion of revenue attached to the collaboration strategy must be seen in relation to one specific drug, i.e. Lipitor. However, removing Lipitor from the sample shows that six of the products obtained through collaboration equal the value of the ten products developed in-house.

- GSK

The document analysis clearly illustrates the growing importance of collaborations, revealing that GSK has obtained twice as many drugs through collaborations as through its R&D since the GSK merger in 2000.

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[20] M&As were included in order to obtain a full picture of the importance played by all the different strategies.

[21] It is important to note that Pfizer did not include all the products, only the key products.

- AZ

The document analysis reveals little innovative activity related to either strategy, showing that: i) the vast majority of their drugs stem from the originating companies, i.e. Astra or Zeneca ii) AZ has not launched any new drugs since 2004 and iii) only three products have been obtained through collaborations since the merger. With this as a starting point, it is interesting to point out that AZ's more formalised strategy of entering into biologics through collaborations seems to have paid off, as the case study shows that the initial collaborations with CAT and Abgenix, together with the later acquisition of MedImmune, alone account for 25% of its development of AZ's pipeline today.

Whilst the findings that GSK has obtained twice as many drugs from collaborations as from its R&D in the recent years and AZ obtained 25% of its development portfolio through its collaborations with CAT and Abgenix provide evidence for the increasing importance of collaborations as means for obtaining drugs, the finding that the value of the drugs Pfizer obtained from collaborations is higher than those from Pfizer's own in-house activity ultimately shows that collaborations have had a greater impact on Pfizer's performance than its R&D directly. It is important to note that whilst most of the drugs stemming from collaborations were obtained from small firms, only a few were obtained from universities.

Whilst the drug data provides objective evidence for the increasing importance played by collaborations, the patent data seems to provide a deeper understanding of this by showing that the number of patents has gone down in the post merger period.

As seen in chapter 4, the particular finding that the number of patents has gone down in the post-merger period holds for Pfizer and GSK only. Importantly, the time involved in filing patents (i.e. six to eight years according to Nightingale and Martin, 2004), means that

although the decrease is particularly significant in the post merger period (after 2000), the lowered innovative activity must be seen as taking place before the merger. This corresponds directly to statements made by interviewees at GSK that there was a vulnerability of R&D that drove GSK to merger in the first place. Despite clear indications that it takes time before firms manage to settle into the new firm (see section 5.2.1), the fact that there has been lowered innovative activity over the 10 years provides a better understanding for the growing increase in collaborations for obtaining new drugs.

7.2.2 Implication for theory: a new face of absorptive capacity and its importance for complementarity

As seen in section 5.2.8, the dimensions of the new role of R&D fit directly with Cohen and Levinthal's (1990) definition of absorptive capacity: "ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (p. 2). Emphasising the importance of identifying potential discoveries, the similarity is even more apparent, i.e. the role or ability to identify and evaluate the potential of new collaborator's discoveries and to develop them. However, the fact that this role of R&D seeks to identify externally invented candidate drugs rather than to acquire knowledge for big pharma to invent drugs in-house, shows that this role of R&D is somehow different from the original idea of Cohen and Levinthal (1989), and gives some indication that this is a new face or type of absorptive capacity. Although different from the original version of absorptive capacity, the finding that this new role requires active engagement and investments in R&D is clearly consistent with Cohen and Levinthal's theory (1989, 1990). The importance of investing and carrying out R&D for all the dimensions of this new face of absorptive capacity is evidenced in the quotes below, i.e. while the first emphasises the importance of carrying out research in order to identify external opportunities and value their potential,

the second supplements it by stressing that only by investing in R&D is a firm able to develop the externally developed candidate drug.

"If we became a pure development and commercialisation activity, I think we would have trouble because we wouldn't be able to find the right entities, to know what's out there, and you certainly wouldn't know what to have developed".

"If they only are evaluating other people's ideas they probably won't be well placed taking them forward".

A deeper understanding of the importance played by research was found in the investigation into the key processes enabling the key roles of 'identification' and 'evaluation' of externally developed opportunities.

Interestingly, whilst big pharma has formed special departments that are responsible for identifying opportunities, most of the opportunities are gained through scientists being 'connected' to a wider scientific environment. Whilst the typical emphasis of 'connectedness' is that it enhances a firm's absorptive capacity (Cockburn and Henderson, 1998), the finding that it leads to most of the partnering opportunities is new. Also, this research finds that due to a gap in the knowledge base between universities and big pharma, big pharma acquires from universities more strategic knowledge about which technologies and areas they need to steer the business into. This knowledge ultimately shapes big pharma's decision of whom to collaborate with.

Whilst identification is primarily dependent on scientists' connectedness to a wider scientific environment, the finding that evaluation relies on scientists' basic knowledge provides direct evidence for the underlying idea behind Cohen and Levinthal's theory

(1989). Whilst the cross case interviews highlight that the importance of new opportunities being reviewed by the relevant departments (see section 5.3), the best evidence for the idea that some level of basic knowledge is needed to evaluate comes from the case study, showing that AZ's externalisation programme for biologics is moved to MedImmune (which used to be one of the biggest biologics companies in the world before it was bought up by AZ) (see section 6.5.2).

Whilst the new role of R&D was seen as a result of a division of labour taking place in the pharmaceutical industry, the importance of research for this role has clear implications for the division of innovative labour. In particular, whilst Arora and Gambardella's theory on the division of labour suggests that large firms can focus solely on development, the interview data seems to contradict this, emphasising that for big pharma firms' capability in development to be effective, they still have to invest in research, i.e. only by investing in its research is big pharma able to identify collaborators, and evaluate and develop small firms' inventions.

Whilst the importance of carrying out research has implications for the division of innovative labour literature, the above seems to provide some insight into complementarity.

At a simple level, the fact that the research provides evidence that R&D activities, together with direct inputs from universities, enable the big pharma firms to identify and evaluate their potential collaborators shows that the various strategies are complementary. Although it is important to note that the research does not provide evidence for complementarity, the fact that identification and evaluation are roles of absorptive capacity emphasises the important role absorptive capacity plays in complementarity and the research can hence contribute to the current debate on what the source behind complementarity is.

7.3 Collaborations' limited impacts on capability building

Given that the first finding is that the key role of R&D is increasingly becoming to identify collaborators, and to evaluate and develop their inventions, it is intriguing to note that *collaborations have limited impacts on capability building. Instead, the research finds that capability building in big pharma primarily relies on acquisitions.* This finding is confirmed across the various studies. Though indicative rather than conclusive, a first insight into the finding that collaborations have little impact on capability building was obtained through the archival data (see chapter four), showing that none of the drugs originated from the key collaborations, which were used to enter into genomics or biologics. More interestingly, the cross case interviews indicated that, whilst capability building is only possible under certain collaboration criteria (section 5.2.5), carrying out acquisitions of specific niche firms still seemed to be the preferred strategy to obtain a more 'definite position' in a new area (section 5.2.6). The ultimate evidence for this finding comes from the AZ case study. More particularly, the investigation into the key processes enabling AZ to acquire knowledge from its collaborators, Abgenix and CAT (i.e. part of research question two), and the actual effects of the collaborations that AZ used to enter into MAbs, revealed that whilst AZ's ability to acquire some knowledge from the collaborations seems to be supported by the collaboration criteria identified in the cross-case interviews (section 5.2.5), full-scale capabilities in MAbs were only obtained after AZ had acquired CAT and MedImmune (section 6.5.2). The latter finding was further supported by the remaining investigation of research question two, showing that only by acquiring CAT was AZ able to assimilate, transform and further exploit (generate new discoveries) MAbs. The finding that AZ could acquire some knowledge but not build full scale capabilities in MAbs gives a more nuanced picture of the degrees to which learning is taking place in firms than found in the extant literature. Hence, in order to gain a deeper insight into this contribution, the underlying evidence of this finding will be discussed in light of the extant literature. In terms of focus, section 7.3.1 seeks firstly to provide insight

into the collaboration criteria that were identified through the cross-case study. Section 7.3.2 seeks to provide evidence that the identified criteria enabled AZ to acquire knowledge from its collaborators. The section also seeks to pose a theoretical explanation for the collaborations failing to build innovative capabilities. The section ends with a deeper insight into the key processes that enabled AZ to assimilate, transform and exploit knowledge after AZ had acquired CAT.

7.3.1 Large scale and key collaboration criteria

As seen in chapter five, the finding that capability building is only possible under certain collaborations criteria was obtained through the investigation into the importance of licensing agreements, option-based and large scale collaborations for capability building. Whilst there is a gap in the literature with regards to the distinctive effects that the different types of collaboration have for capability building (as acknowledged in section 2.4.1), the rationale for including in-licensing agreements and large scale collaborations was that they were seen to represent the extreme ends of the biopharma partnering continuum (Atun, 2007) and, hence, were seen to have the potential to spark contrasts in answers. Option-based collaborations were included due to clear indications that these are the most frequently used collaborations. Given that the latter types are joint R&D agreements (see 5.2.3), this finding seems to be in line with Roijakkers and Hagerdoorn (2006), who claim that collaborative R&D agreements are most frequently used in the pharma industry.

The subsequent investigation into the distinctive effects of licensing agreements, option-based and large scale collaborations on capability building interestingly showed that, whilst the former two were rejected as means to build new capabilities by all the interviewees, most of the interviewees were positive regarding the potential of large scale collaborations. Surprisingly, whilst the term large scale collaboration was used to cover the

larger collaborative agreements, an interviewee claimed that joint ventures and collaborative research, in addition to in-sourcing, are the only types of collaboration that have an impact on capability building.

The key argument underlying the claim that a collaboration has to be 'over a certain size' in order to have potential for capability building was that, although large scale collaborations, in the same way as smaller scale collaborations, are primarily motivated by the need for products rather than learning, the extensive resources allocated to large scale collaborations, as well as the wider involvement of the firms, lay a greater basis for the necessary learning needed to build capabilities. Whilst the former confirms the importance of the size of the resources for a firm's ability to acquire knowledge (Devlin and Bleackley, 1988), big pharma's lack of involvement in the early stages of development seemed to be one of the key reasons for the limited impact that in-licensing and option-based collaborations have on capability building. An interview with a Senior Manager in R&D provides a deeper understanding of this, emphasising that learning depends on scientists' own validations of the data. Hence, as the scientists do not have the opportunity to personally validate the data, as this part is often carried out by the smaller firms, there is little opportunity for learning.

Whilst the lack of involvement in the early stages of product development is a cause for rejecting in-licensing agreements and option-based collaborations for capability building, the key reason for rejecting them is related to the finding that it is small firms that want to learn from big pharma rather than vice-versa, a finding which is not taken account of in the extant literature. As seen in section 5.2.5, the interviewees' view entails small firms seeking to access big pharma's capabilities in the later stages of drug development, capabilities that are described as more 'evolutionary' (Arora and Gambardella, 1990). This must be seen in the context of the new firms being new players, often university spin-offs

(Kneller, 2003), which, although they have excellent research skills, lack knowledge in development, as emphasised in the section above, i.e. 7.2.

Interestingly, the same senior managers further argued that the drive of small firms to learn from big pharma has had clear impacts on the nature of big pharma-small biotech collaborations over time, claiming that small firms' urge to learn has been the key driving force for the increasingly interactive elements that now characterise big pharma-small biotech collaborations. With the above suggesting that it is small firms' desire to learn from big pharma that has caused the increasingly collaborative interaction in these types of collaborations, this seems to undermine Hagedoorn's (2006) claim that the growing trend of collaborative research collaboration since 1985 is driven by big pharma having internalised biotech knowledge.

Whilst large scale clearly must be seen as a key criterion for capability building, the same interviewee who highlighted the importance of join ventures, collaborative research and in-sourcing also emphasised the following additional criteria for collaborations to have an effect on capability building, i.e. endorsement from the higher levels of the firm, creating the right environment, and champions on both sides of the collaborations. Whilst the first factor, i.e. endorsement, seems particularly applicable for large scale collaborations, given the extensive resources and time involved with large scale collaborations make these collaborations more likely than in-licensing agreements and option-based collaborations to have been endorsed at a higher level at the firm, the arguments used to reject in-licensing and option-based collaborations also enforce the importance of 'creating the right environment' (also found in Cockburn and Henderson, 1998). In particular, scientists emphasised that bad filing systems and unwillingness to share knowledge on the part of small firms, and arrogance on the part of big pharma, were key factors for in-licensing and option-based collaborations failing to learn from each other and build capabilities. Also, in-

licensing agreements and option-based collaborations were not seen to allow sufficient time to learn the general science that lies behind the inventions.

Comparing the potential of the in-licensing agreements, large scale and option-based collaborations with their underlying strategic motivation of enhancing product markets of the firms involved, as found in Hagedoorn (1993) who finds that large scale collaborations, such as joint ventures, and research contracts are strategically motivated, and in-licensing agreements are not, the research finds that both large scale collaborations and in-licensing agreements are in line with their underlying strategic motivation. However, with regards to option-based collaborations, although there is a strategic drive, the research finds that, as big pharma does not want to learn from small firms, they are not congruent with their strategic motivation, at least for big pharma.

7.3.2 Knowledge acquisition – learning – capability building

In light of the above, it is interesting to note that AZ formed two large scale collaborations, namely with Abgenix and with CAT, as means to enter into MAbs. The scale of the collaborations can be illustrated by their formal aspects: i) the objectives of the Abgenix and CAT collaborations respectively were set to reach 36 and 25 targets over three and five years, ii) in the region of $100 million each, and iii) the extensive resources committed to each of the collaborations, i.e. AZ allocated approximately 40 employees in the respective therapy areas and Abgenix and CAT committed around 50% of their R&D capacity to their collaboration with AZ.

Interestingly, the explicit investigation into acquisition (carried out as part of research question two), showed that knowledge acquisition seemed to depend on exactly the factors obtained in the cross-case study (i.e. respectively sections 6.7.1, 5.2.5 and 5.3.2). Although

it is important to note that these were not sufficient to build full scale capabilities (as AZ had to acquire CAT and MedImmune), this section seeks, by linking the different criteria to the interviewees' perceptions of learning, to provide evidence that they enabled AZ to acquire some knowledge of MAbs .

Interestingly, the investigation into acquisition shows that it was AZ's early work in MAbs that *'pushed through'* the decision to enter into MAbs. Consistently with Cohen and Levinthal (1990), the in-depth investigation into the key processes that enabled AZ to acquire knowledge from the collaborators provided a deeper insight into this, showing that for a firm to learn in this area, it needs some level of background knowledge. Whilst the importance of *prior knowledge in the field in which the collaborator operates* was highlighted in the pilot study, the case study showed that prior knowledge had clear effects on the structure of the collaborations. In particular, the interviewees stressed that, besides the fact that the most senior Scientist in MAbs at AZ had become the lead scientist of the first collaboration, the work on the different targets were managed by one of the most senior staff from each of the sides of the collaborating firms. Whilst this provides a strong case for confirming Cohen and Levinthal's (1990) point about prior knowledge, the finding was undermined by indications that it was the development teams – given that they had no knowledge in the field – that had learnt the most in the collaborations.

As seen in the case study, whilst the findings that most senior scientists in the partnering firms were put in the most central roles was taken as evidence that there were *champions on both sides of the collaborations*, it is interesting to note that interviewees reported that they had obtained some learning in terms of 'how to develop MAbs' in the daily work, giving some clue that champions on both sides of collaboration can have a positive impact on learning. In light of the fact that the importance of champions is highlighted in the

literature (e.g. Saez *et al.*, 2002) yet there is little evidence of their actual effects, this finding seems to provide insights into the latter.

Although some learning was achieved in the daily work, the more scientific knowledge was obtained in *project review meetings*, where the different antibodies were discussed in light of their underlying science, e.g. what were they expected to do? This finding is coherent with the finding presented above that scientists need to personally validate the data in order to learn from collaborators. As seen in the case study, the learning obtained through the review meetings clearly benefited from a supportive culture, i.e. where the scientists were eager to share their knowledge. Interestingly, in both the cases, a *supportive culture* was clearly related to AZ *involving their partners right from the start of the collaborations*.

In particular, as seen in section 6.6, a Senior Manager at AZ pointed to AZ's active efforts to involve Abgenix in identifying the targets for the collaboration, holding that the R&D staff at Abgenix felt more motivated to deliver and engaged in the projects. As indicated in the same section, whilst the interview data indicates that the way AZ involved Abgenix in the selection as targets was *'unusual'*, the interviewees paradoxically recognised that treating Abgenix as a contract research organisation, which would have been hired to work on a set number of targets, would have had *"a very different outcome"*.

Whilst the CAT was also involved from the start, it interestingly showed that they initially included all staff, not only in R&D. With regards to the finding that arrogance on the part of big pharma is one of the key factors preventing learning from taking place between small biotech firms and big pharma, interviews with Senior Managers emphasised the importance of AZ having been *supportive of CAT's ideas*. Interestingly, whilst the cross-case study shows that involvement is key for big pharma learning from small firms, this

provides evidence that involving the small firm not only has an impact on the level of motivation of the small firm but also that it positively contributes to a suitable learning environment.

In addition to the fact that the flow of knowledge was ensured both through the daily work and meetings, it is also interesting to note that AZ set up a *database* in relation to the first collaboration with Abgenix. Providing an excellent tool to store the relevant ideas related to the different projects, as well as to ensure an effective way of assimilating all relevant data regarding the projects between the collaborating firms, the database was replicated not only to CAT but also to the small molecule activity.

Whilst the above shows that the various processes contributed to learning, the findings that it was prior knowledge in MAbs that made AZ seek to enter into MAbs in the first place, in addition to the fact that it seemed to have a clear effect on the organisation of the collaborations, as well as that AZ identified most learning taking place through project review meetings, illustrate the particular importance played by these processes for *'acquisition'*. On overall, the case study shows that AZ gained some insight into how to develop MAbs as well as some the underlying scientific knowledge through its large scale collaborations.

Though there was a general perception that AZ obtained more learning from forming a large scale collaboration than it would have obtained from a small one, as illustrated in the quote *"I think we could have got some learning from a smaller scale collaboration but nothing like we got"*, the fact that only by acquiring CAT and MedImmune did AZ obtain capabilities in MAbs provides objective evidence for the finding that collaborations failed to build innovative capabilities. The failure to build innovative capabilities through collaborations is paradoxical, not least because AZ entered into two large scale

collaborations, but also because of the extensive resources and time involved, and the significant innovation output.

The finding that through collaborations AZ was able to acquire some knowledge in how to develop MAbs as well as the scientific knowledge underlying MAbs (and hence improve its absorptive capacity), but not to build full scale capabilities, seems to suggest that certain types of the knowledge were too *sticky* (von Hippel, 1994) to build capabilities. Interestingly, although the concept of stickiness of knowledge appeared in literature just after the introduction of absorptive capacity, the implications of this distinctive characteristic of knowledge have not been taken account of in the absorptive capacity literature.

As suggested in the introduction to this section, the idea that firms can acquire some knowledge, but not build capabilities, provides a more nuanced picture of the degrees to which the firms learn than found in the literature. Specifically, whilst Leonard-Barton (1995) holds that "the prime engine for [...] the creation and growth of technological capabilities is the development of new products and processes" (xiii), but does not give any insight into the process of building technological capabilities, Lane and Lubatkin (1998) treat learning and capability as one and the same. Also, rather than seeking actual evidence for learning and capability building, Lane and Lubatkin's (1998) methodology is based on 'expert' evaluations only.

Whilst the fact that AZ only obtained capabilities in MAbs by acquiring CAT provides the ultimate evidence for the finding that collaborations have limited impacts on capability building, a further confirmation of this is that the wider *assimilation* of MAbs only happened after AZ had acquired CAT. Interestingly, as seen in the case study, there was no formal goal to assimilate CAT or Abgenix's knowledge outside the collaboration, i.e. not

even to the collaborations' associated therapy areas. i.e. Oncology and Respiratory and Inflammation. Furthermore, whilst the research found that AZ did not put any formal processes in place to assimilate knowledge, the finding that informal processes played an insignificant effect on knowledge assimilation provides the ultimate evidence that there were no interfaces in place to assimilate the knowledge among the subunits within the firm (Cohen and Levinthal, 1994). Given that absorptive capacity requires assimilating the new knowledge (Cohen and Levinthal, 1989, 1990) in the firm, the fact that AZ did not put any explicit measures in place to assimilate CAT and Abgenix's knowledge must hence be seen as one of the key reasons for AZ's failure to build new capabilities through the collaborations.

In terms of the specific processes that AZ used to assimilate its acquired CAT knowledge throughout AZ, the case study shows that AZ actively set up internal collaborations between the recently acquired CAT and two new therapy areas. In light of clear indications in the cross-case study that when the acquired firms' knowledge is assimilated, this only occurs through the occasional meetings (see section 5.2.6), setting up internal collaboration between an acquired firm and new therapy areas seemed to be a new method for assimilating and further exploiting the knowledge of the acquired firms. Interestingly, the internal collaborations were seen as part of a broader strategy, where AZ sought to use MAbs in new areas where they are not traditionally used (see section 6.5.2).

As seen in the case study, the internal collaborations laid a basis for investigating the key processes behind transformation. Interestingly, whilst the pilot study showed that *'transformation'* relies on tacit processes and, hence, seemed to confirm the claim by Lane *et al.* (2002), the case study seemed to suggest that transformation was obtained by combining AZ's ability to define niches in the market with the CAT's more specific knowledge of how to develop MAbs. In addition to this finding's emphasis on the

importance of combining new knowledge for innovation, this strategy of setting up internal collaborations between CAT and MAbs has proved successful, given the clear indications that *'a healthy number of products'* are stemming from these internal collaborations. Although the importance of the role that new knowledge plays for innovation was emphasised, it does not mean that lead to capability building, i.e. CAT is still responsible for all the research on MAbs.

In terms of exploitation, it is interesting to note that whilst Lane and Lubatkin (1998) find support for dominant logic, i.e. "a firm's preferences for projects of a given type, size, and risk level" (Grant, 1988, in Lane and Lubatkin, 1998, p. 466), this research finds both in the cross-case interviews and the case study that exploitation requires some pre-set measures to evaluate the potential of the knowledge, i.e. what they call 'proof of concept'. It is important to note that 'proof of concept' is an industry specific measure.

By extending the initial focus from collaboration to acquisition, this is one of the first studies, if not the first, that sheds light on the practices behind knowledge acquisition. Interestingly, whilst a more general investigation into the key processes behind the absorptive capacity, as was carried out in the pilot study, clearly showed that those processes that were particularly related to assimilation depended on tacit knowledge and hence seemed to confirm Lane *et al.* (2002), the fact that some insight, though sparse, was obtained through a more focused case study suggests that, only by focusing the investigation on a specific context will it have the potential to elicit the key processes governing absorptive capacity.

7.4 Conclusion

The research finds that R&D has changed its focus in relation to the increasing reliance on collaboration over the recent years and that its key role is to identify, evaluate and develop external discoveries. Although this role fits Cohen and Levinthal's (1990) definition of absorptive capacity, the fact that this role identifies collaborators and potential bio-drugs, rather than acquiring the knowledge to generate own discoveries, suggests that this is a new face of absorptive capacity. Though different than the original idea of absorptive capacity, the research shows that the role requires an investment in R&D, confirming the underlying idea in Cohen and Levinthal's theory (1989, 1990, 1994). The investigation into the key processes that enable the specific roles of 'identification' and 'evaluation' provides an even deeper insight into the importance of R&D, showing that they respectively depend on scientists' connectedness to a wider scientific environment and their basic knowledge (the latter is in direct line with Cohen and Levinthal, 1989, 1990). Given that the new role of R&D must be seen as a result of the increasing reliance on collaborations and their underlying organisation (where big pharma is responsible for drug development), the research argues that a new face of absorptive capacity has evolved in response to the increasing division of innovative labour taking place in the pharmaceutical industry. Interestingly, though big pharma's collaborations are found to have limited impact on capabilities, the research shows that under certain collaboration criteria, i.e. prior knowledge in the field in which the partnering firm operates, champions on both sides of the collaboration, and a supportive knowledge environment, the firm is able to acquire some knowledge and, as such, improve its knowledge potential to arguably to become even better at identifying and evaluating the potential of new collaborators.

Chapter 8:

Conclusion

Inspired by the widely accepted theoretical assumptions that extramural knowledge plays a crucial role for innovation, and firms can have the ability to acquire knowledge from external sources, the motivating question for the research was: *how do firms acquire the knowledge and capabilities to move into new areas?*

'Big pharma' seemed to provide an intriguing context for the investigation of this question. This rested at least on two aspects. Big pharma has, over the last decades, seen the rise of biotechnology offering new technologies and techniques for drug innovation that are fundamentally different from their traditionally chemistry based approach to drug innovation. Hence, much of the extant knowledge in biotechnology emerged outside of 'big pharma'. However, despite the exponential increase of its investments in internal and external R&D since the introduction of biotechnology, 'big pharma' is currently experiencing a severe R&D inefficiency, providing a reverse picture than theoretically expected.

The idea that firms have an ability to acquire extramural knowledge is principally associated with the absorptive capacity literature, introduced by Cohen and Levinthal (1989, 1990, 1994). Absorptive capacity was introduced as a by-product of R&D, i.e. by investing in R&D, the firm obtains the capacity to acquire, assimilate and exploit knowledge (Cohen and Levinthal, 1989). Recognising the importance of this concept, Lane and Lubatkin (1998) extended the use of absorptive capacity to collaboration, introducing

what they call 'relative absorptive capacity'. By building on the works of Cohen and Levinthal (1989) and Lane and Lubatkin (1998) this research treated R&D and collaboration as distinctive knowledge acquisition strategies. Inspired by the aforementioned empirical motivation, the first aim of the research is to investigate the respective effects of the two knowledge acquisition strategies. Recognising that innovation is "the primary engine" to build new technological capabilities (Leonard-Barton, 1995), the research sought, in addition, to investigate the strategies' distinctive impacts on innovation and also their effects on capability building. Building on the above, research question one sought to investigate the respective effects the two knowledge acquisition strategies have for big pharma's innovation and capability building: '*How important have the two key strategies identified by the AC literature (R&D and collaborations) been for pharma's ability to produce new drugs and to build capabilities?*'

Intriguingly, despite a widespread use of the concept of absorptive capacity since its introduction by Cohen and Levinthal (1989), there have been few efforts to investigate the practice behind it. Recognising not only this gap, first identified by Lane *et al.* (2002), but also that the gap extends to the key processes involved in the collaborations, research question two sought to identify the key processes that enable a big pharma firm to acquire, assimilate, transform and exploit knowledge from collaborators: '*What are the key processes and capabilities that enable a top pharmaceutical firm to acquire, assimilate, transform and exploit knowledge from collaborators?*' The underlying theoretical framework for this research question is taken from Zahra and George (2002), who propose that each of the dimensions of absorptive capacity, i.e. acquisition, assimilation, transformation and exploitation, are capabilities governed by specific processes.

Whilst research question one was investigated through the use of multiple case studies on three big pharma companies, including both document analysis of each of the firms, as

well as interviews, research question two relied on an in-depth case study on two large scale collaborations that one of the sample firms used as means to enter into monoclonal antibodies. The rationale for choosing different methodologies for the research questions was that, whilst a comparison was regarded important to obtain a picture of the importance played by R&D and collaboration for innovation and for capability building for big pharma, only by carrying out a case study would the research obtain the richest possible insight into the key processes behind absorptive capacity. However, it is important to note that although the cross-case interviews were primarily used to investigate the first research aim, they are also used to pilot the second research aim. On the other hand, as the two aforementioned large scale collaborations were used as means to enter into a new area, the case study can also seek to provide insight into the effects of collaborations on capability building. As such, the case study also serves as an illustrative case for the first aim of the research.

Contribution of this research

As a starting point, the research shows that big pharma firms are increasingly using collaborations to acquire new candidate drugs from the small niche biotech firms to enter into the new areas, as a direct result of big pharma failing to innovate in recent years (e.g. due to the scope of science and technology needed in the different therapy areas being too wide). In light of clear evidence of the growing importance of collaborations, and in addition to the fact that big pharma is responsible for the latter stages of drug development in their collaborations with small biotech, the research confirms (though on a small sample) that a 'division of innovative labour' is taking place between small biotech and big pharma firms (Gambardella and Arora, 1994).

Interestingly, the research finds that the role of R&D has changed in light of the importance of collaborations as means for innovation, with its key role identified as being:

to identify and evaluate potential collaborators and their discoveries, and to develop their candidate drugs. In light of the absorptive capacity literature, the research suggests that although this new role seeks to identify externally invented candidate drugs rather than to acquire knowledge for big pharma to invent drugs in-house, it fits Cohen and Levinthal's (1990) definition of absorptive capacity: "ability to recognize the value of new information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990:2). As this role has changed in relation to the increasing importance of collaborations, this research argues that this is a new face of absorptive capacity, which has evolved in the light of the division of innovative labour. Interestingly, given that most of big pharma is in a situation where they are facing patent expiries on their drugs and need to replace them quickly, this role of R&D, or new face of absorptive capacity, is regarded as being of even greater importance in the future.

Though arguably a new face of absorptive capacity was discovered, the research finds that only by carrying out research is big pharma able to identify collaborators. The finding that this new role requires active engagement and investments in research provides direct evidence for Cohen and Levinthal's conclusion. The investigation into the key processes behind this type of absorptive capacity provides an even deeper understanding of the importance played by research for this: identification primarily depends on scientists' 'connectedness' to a wider scientific environment, whilst evaluation relies primarily on scientists' basic knowledge. The latter lays at the heart of Cohen and Levinthal's theory (1989).

Hence, the finding that the new key role of R&D requires investment in research has clear implications for division of labour, which suggests that large firms can solely focus on their key capability in development, and also for big pharma, which currently is cutting investments in research. Building on the evidence obtained in this research, cutting R&D

seems not only to have a direct implication for their ability to identify, evaluate and develop externally generated drugs, but also, given that most of the collaboration opportunities come from scientists' own research networking activities, it seems questionable whether, by cutting down on research, the scientists will have the same opportunities to identify suitable collaborators. Cutting research expenditure seems to have particularly severe implications in the long term, especially if big pharma will seek to obtain candidate drugs in an early stage.

Significantly, despite the finding that the key role of R&D is to identify collaborators, the collaborations seem to have limited impact on capability building. Instead, the research finds that capability building in big pharma primarily relies on acquisitions.

Though lack of involvement in early stages in option-based collaborations is one cause of capability building not being acquired, the key reason for the failure of this type of collaboration to build capabilities is that it is small firms that want to learn from big pharma rather than vice-versa. In fact, the research finds that small firms' urge to learn has been the key driving force for the increasingly interactive elements that now characterise big pharma-small biotech collaborations. The finding that it is the small firms' desire to learn from big pharma that has caused the increasingly collaborative interaction in this type of collaboration seems to undermine Hagedoorn's (2006) claim that the growing trend of collaborative research collaboration since mid 1980s was driven by big pharma having internalised biotech knowledge.

The cross-case study found that only under the following circumstances large scale collaborations had the potential for capability building: (i) the big pharma firm having prior knowledge in the field where the collaborator operates, (ii) the big pharm firm being involved in the early stage of product development, and (iii) project champions being

present on both sides of the collaborations. The in-depth case study later proved to build exactly on these criteria and hence, provided an ideal setting to test the criteria. Interestingly, although these processes were found to support some level of knowledge acquisition (evidence was obtained through combining the processes with learning perceptions), the case study shows that only by acquiring one of the collaborator firms, was the big pharma firm able to obtain full scale capabilities in the new area. Whilst the former provides some insight into the key processes enabling a firm to acquire knowledge from a collaborator, the finding that only by setting up 'internal' collaborations between the acquired firm and new therapy areas can knowledge assimilation be affective, suggests that knowledge assimilation requires some formal processes. The case study illustrates that transformation relies on combining different capabilities for innovation. Exploitation, on the other hand, requires some pre-set measures to evaluate the potential of the knowledge. Although by extending the initial focus of research question two (including the processes after the partnering firm was acquired) the research was able to investigate the processes behind the theoretical framework, it is important to note that this research only provides a first insight into the practice of absorptive capacity.

The finding that *some* knowledge was acquired by big pharma companies from collaborations, though not sufficient to build innovative capabilities, provides a more 'nuanced' understanding of the degrees to which learning is taking place in firms, compared with the accounts found in the extant literature. The fact that the student firm was not able to build full scale capabilities in the new area seems to suggest that certain types of the collaborator's knowledge appeared too 'sticky' (von Hippel, 1994). Interestingly, although the concept of stickiness of knowledge appeared in literature just after the introduction of absorptive capacity, the implications of this distinctive characteristic of knowledge have not been taken account of in the absorptive capacity literature.

To recap, the finding that a firm can acquire some knowledge through collaborations suggests that the new face of absorptive capacity can improve the knowledge potential of the firm, arguably becoming more effective at identifying and evaluating extra-mural opportunities.

Limitations of the research

The main limitation of this research is the small sample size, hence the research cannot claim external validity and the findings cannot be generalised. Despite this, the chosen methods have proved to improve the reliability of the research, e.g.: i) the key finding that the key role of big pharma is to identify and evaluate potential collaborators and their discoveries, and to develop their candidate drugs, was supported by the importance collaborations were found to play for innovation in the archival analysis. ii) Though collaborations were found to be crucial for innovation both in the archival analysis and cross-case interviews, the cross-case interviews and the case study provided a deeper understanding of the importance different types of collaborations play for capability building, offering a more nuanced picture of inter-organisational learning. iii) By investigating the key processes that enable a firm to acquire, assimilate, transform and exploit knowledge from a collaborator both through the cross-case interviews and the case study, the research obtained a deeper insight into the idiosyncratic nature of absorptive capacity. Hence, though the research does not claim external validity, the chosen methods have provided credibility to the research, which on overall has provided some new insights into the importance of absorptive capacity.

Further research

The research has provided a deeper understanding of absorptive capacity and the specific findings provide new avenues for future research.

Whilst a first insight into the practice of absorptive capacity is obtained in the study, more research into the processes governing the different dimensions of absorptive capacity is needed. Given that some of the processes were found to build on tacit components, future research could benefit from a more involving research, e.g. participant observation, than interviews.

Furthermore, the importance of investigating the practice of absorptive capacity is enhanced by the suggestion that knowledge absorption is inhibited by the stickiness of knowledge, hence further research should aim at identifying the processes which help to 'un-stick' knowledge, addressing a clear gap in the extant literature.

Finally, given that the research has identified a new face of absorptive capacity, more research is needed to understand its applicability, i.e. the extent to which this type is of importance and impact for other types of firms and in different industries.

Appendices:

Appendix A: M&A activity of Pfizer, GSK, AstraZeneca and Merck

1. Pfizer Inc, New York

Year	M&A	New name: (current name)	Specifics:
1953	Acquisition of J.B. Roerig and Company		J.B. Roerig and Company were specialists of nutritional supplements, became a division of Pfizer
1971	Acquisition of Mack Illertissen		Mack Illertissen was a prosperous manufacturer of pharmaceutical, chemical, and consumer products oriented to the German market.
1983	Acquisition of Taito		Pfizer had partnered with Taito to manufacture and distribute antibiotics since 1955
1995	Acquisition of SmithKline Beecham's animal health business		The acquisition makes Pfizer a world leader in the development and production of pharmaceuticals for livestock and companion animals in 1995
2000	Merger with Warner-Lambert co	Pfizer	The merger with Warner-Lambert brought together two of the fastest-growing companies in the pharmaceutical industry. With Warner-Lambert, Pfizer gained product lines ranging from branded pharmaceuticals from once world leader drug producer Parke-Davis (Parke-Davis and Warner-Lambert merged in the early 1970's) and Agouron (previously acquired in 1999 by Warner-Lambert) to wet-shave products from Schick (a product line acquired by Warner-Lambert in 1970'ies) and Wilkinson Sword (acquisition made in 1993). In 1996, Warner-Lambert and Pfizer formed a co-marketing agreement for Liptor, the largest-selling pharmaceutical worldwide.

2003	Merger with Pharmacia Corp.	Pfizer Inc	Pfizer Inc and Pharmacia Corporation forged one of the world's most valuable companies. Pharmacia was the new name of the company, as it in 2000 had merged with Monsanto and Searle (Monsanto, however, spun off in 2002, before the merger with Pfizer). Before 2000, Pharmacia was called Pharmacia & Upjohn Inc, as Pharmacia and Upjohn had merged in 1995 (prior to the merger the companies were as Pharmacia AB and The Upjohn Company). Pharmacia & Upjohn had been a global provider of human health care products, animal health products, diagnostics and specialty products.

2. GlaxoSmithKline, London

Year	M&A:	New name: (current name)	Specifics:
1958	Glaxo acquires Allen and Hanburys Ltd		
1959	The Wellcome Foundation acquires Cooper, McDougall and Robertson Ltd		Cooper, McDougall and Robertson Ltd is an animal health company founded in 1843.
1963	Smith Kline and French acquires Recherche et Industrie Therapeutiques (RIT)		RIT was specialised in the vaccines business
1978	Glaxo acquires Meyer Laboratories Inc.		With this acquisition, Glaxo's business in the US started. Glaxo becomes Glaxo Inc from 1980.
1982	SmithKline acquires Allergan		Allergan, an eye and skincare business. However, spun off from SmithKline in 1984.
1982	SmithKline merges with Beckman Instruments Inc	SmithKline Beckman	Beckman Instruments Inc was a company specialising in diagnostics and measurement instruments and supplies.
1986	Beecham acquires Norcliff Thayer		With the acquisition, Beecham added both tablets and skin care to its portfolio.
1988	SmithKline BioScience Laboratories acquires International Clinical Laboratories, Inc		International Clinical Laboratories, Inc, was one of the company's largest competitors. The acquisition increased the company's size by half and established SmithKline BioScience Laboratories as an industry leader.
1989	Merger between Smithkline Beckman and Beecham group Plc	Smithkline Beecham Plc	
1994	SmithKline Beecham purchases Diversified Pharmaceutical Services, Inc.		Diversified Pharmaceutical Services, Inc was a pharmaceutical benefits manager (consulting company in management of change and development)
1994	SmithKline Beecham aquires Sterling Health		This acquisition makes SmithKline Beecham the third-largest over-the-counter medicines company in the world and number one in Europe. With the intention of focusing on human healthcare, SmithKline Beecham sells its animal health business.

1995	Merger between Glaxo Plc and Wellcome Plc	Glaxo-Wellcome Plc	
1997	SmithKline Beecham and Incyte Pharmaceuticals create a joint venture: diaDexus		The purpuse of the joint venture was to discover and market novel molecular diagnostics based on the use of genomics.
1998	Glaxo Wellcome acquires Polfa Poznan		.
1999	SmithKline Beecham divests SmithKline Beecham Clinical Laboratories and Diversified Pharmaceutical Services.		
2000	Merger between Glaxo-Wellcome Plc and Smithkline Beecham Plc	Glaxosmithkline	

3. AstraZeneca, London

Year	M&A:	New name: (current name)	Specifics:
1960's	Atlas Powder Company acquires The Stuart Company		At the same time, Atlas Powder Company changed its name to Atlas Chemical Industries. After the acquisition, The Stuart Company was renamed Stuart Pharmaceuticals and became a division of ACI
1972	Imperial Chemical Industries Ltd acquired Atlas Chemical Industries		
1982	*Collaborative agreement between Astra AB and Merck*		*The agreement covered clinical trials, registration and marketing in the U.S. of products resulting from Astra's research.*
1987	*Stuart Pharmaceuticals created two marketing companies.*	*Stuart Pharmaceuticals and ICI Pharma.*	*Also, the U.S. pharmaceuticals business was renamed ICI Pharmaceuticals Group.*
1992	*ICI Americas Inc. renamed to Zeneca Inc. and created a new company: ICI Americas Inc.*		*Both the companies were owned by ICI PLC. Zeneca comprised ICI's bioscience businesses, while ICI Americas Inc. incorporated ICI's chemical businesses.*
1994	Joint venture between Astra AB and Merck	Astra Merck Inc.	The new pharmaceutical company was focusing exclusively on marketing, sales and drug development.
1995	Zeneca acquired a 50% stake in Salick Healthcare, Inc		Salick Healthcare, Inc. was a leading cancer treatment organization with comprehensive cancer centres in the major cities in the U.S. Zeneca acquired the balance of Salick in 1996.
1998	Merger between Astra Merck Inc. and Astra USA	Astra Pharmaceuticals, LP.	The new company was a limited partnership between Astra and Merck and formed the US subsidiary
1999	Merger between Astra AB and Zeneca Plc	AstraZeneca	

Appendix B: Interviewees

Interviewees at GSK:

- Vice President of Drug Discovery
- Vice President of IT
- Head of Biometrix
- Scientists
- Responsible Clinical Trails
- Regulation Manager

Interviewees at Pfizer:

- Strategy Manager
- Marketing Manager
- Government Affairs Manager
- Other Senior Managers
- Responsible for pre-clinical and clinical partnering opportunities
- Scientists

Interviewees at AZ:

- CEO
- Vice President for Science Policy and R&D
- Director and Senior Manager, Alliance Management
- Director of Science and Technology Alliances
- Director of Pre-Clinical Deals
- Managers and Senior Managers in R&D
- Regulation Manager

- Scientists and Senior Managers
- Site Leader for R&D

Interviewees from other big pharma:

- Regulation Manager, Johnson&Johnson
- Director of Academic Scientific Collaborations, Merck

Interviewees from the academia:

- Head of Bio-pharma partnerships, Imperial College, London
- Professor in Health Management, Imperial College, London
- Professor of Innovation and Entrepreneurship, Imperial College, London
- Professor in Molecular Neurosciences, University of Warwick*

Interviewees from small biotech firms:

- Founder of Neurosolutions Ltd*, UK
- Founder of Research and Innovation, Italy
- Partners of various small biotech firms
- Clinical Project Managers at Kyowa Hakko Kirin, Japan
- Head of Education at Association of the British Pharmaceutical Industry (ABPI)

*these two are the same person

Other interviewees:

- Self employed consultants

Appendix C: Interview guide

The following is a sample list of questions that were used for the interviews. The questions actually used were adapted according to the role and position of each interviewee.

Interview questions related to research question one

Opening interview questions

In light of the increased R&D investments and a wave of consolidation in the market over the rational design regime:

a) how important have the different firm strategies, in-house R&D, collaborations and M&A's, been for obtaining knowledge from external sources, particularly in biotechnology, and what are their respective effects on innovation and capabilities?

b) do you think the relative importance has changed over time? And what implications, if any, has this had on the firms' R&D?

c) when do you prefer to collaborate and when do you prefer to acquire a company?

d) To what extent have you acquired capabilities in biotechnology, and if so:

- What were the key strategies for obtaining this knowledge?
- How did you implement the new knowledge in biotechnology?
- In what therapeutic areas have you acquired capabilities in biotechnology?

Specific questions on collaboration were informed by the quantitative profiles of the firms.

Collaboration and economic performance:

- From my quantitative profile, it looks like if collaborations are the key strategy for your economic performance, and hence your efforts of collaborating are translated into economic performance? However, much of its contribution comes from Lipitor which is the regarded as the most profitable drug ever. Deducting the contribution from Lipitor, is looks like if the strategies contribute fairly equally. What is your reaction to this? However, given that the recent mergers do not seem to have made you more innovative, does that make you even more dependent on collaborations?

Collaboration and learning

<u>Generic question</u>

- What types of learning are associated with the following different types of collaborations: arm's length's activities of transferring ready-to-use elements of a specific technology or pieces of equipment (similar to a license or consultancy agreement), to collaborative agreements in which a partner undertakes a specified piece of work (depending on whether they have defined the outcome or the problem); to joint ventures designed to solve a problem using combined resources, including reciprocal "in-sourcing" arrangements?

<u>Specific questions</u>

- Do you learn from in-licensing agreements? If so, what types of learning? (e.g. strategic learning?)
- How often do dyadic collaborations occur? What is the motive and with whom do you form this type of collaboration, i.e. small firms, other big firms or universities?

Collaboration and capabilities

Key for this research question is to gather evidence on the extent to which collaborations have enhanced the innovative capabilities, including both direct and indirect benefits, as illustrated in the questions below:

- By looking at the development of this TA, to what extent have collaborations enhanced the innovative capabilities by building expertise in various sub areas?
- Can you give examples of this?
- How many drugs have derived from collaborations, and to what extent did they enhance your expertise in sub areas?
- To what extent have you been able to transfer skills that you have acquired through collaborations? What types?
- Have you been able to start new projects on the basis of what you have learnt through collaboration?
- How are these projects going?

R&D

- What implications, if any, does the increasing reliance on collaborations have for the role of R&D?
- Is the role of R&D merely becoming a way to identify and evaluate the externally developed compounds? And if so, what does such an organisation require in terms of the actual organisation of R&D, as well as management and time?
- To what extent is an internal investment in knowledge, e.g. in biotechnology, really needed? What is a sufficient limit? Would a sufficient limit be the extent to which firms are able to identify and value the external knowledge?

Interview questions related to research question two

- What are the key processes by which the firms source, assimilate, transform and exploit knowledge?

Further interview questions related to acquisition of knowledge

Acquisition of knowledge through collaborations in general:

- What are the key processes involved in identifying a partner, and then to value and acquire the partner's knowledge? In terms of valuing the new knowledge, how important is the ability to assess the partnering firm's absorptive capacity? How important is it to choose collaboration with sufficient strategic interest at the highest level within the firm?
- What are the criteria for selecting a partner, and why? How important are: critical mass, ability to enhance R&D capability, broaden product ranges, access to new technologies, potential costs savings (Hargadon and Sutten, 1997)?

Specific questions on the chosen collaboration:

- What were the key processes involved in identifying this particular collaboration?

Further interview questions related to assimilation of knowledge

- By what means was the acquired knowledge assimilated between your firm and the collaborator?
- What are the key processes for assimilating the knowledge between partners?

Managerial aspects:

- How important is it to manage the 'not invented here' syndrome, to and to communicate goals for the assimilation of knowledge? How is this being done?

Organisational aspects:

- Does organisational structure found in the firms influence the assimilation of knowledge and if so, how? The similarity of organisational structures is positively related with inter-organisational learning (Lane and Lubatkin, 1998)
- Are fluid organisational structures and flexible work practises necessary for an effective knowledge acquisition?
- How important is it to create the right environment for knowledge sharing, and for the flow of 'sticky' information?
- How should work be organised to obtain an effective assimilation of knowledge? Tacit knowledge is best transferred through people working closely together (Polyani, 1958)
- To what extent and how should the partnering firms integrate to ensure an effective assimilation?
- How effective are channels of communication to assimilate knowledge of the partnering firms?

Knowledge aspects:

- How important is it to engage in projects with sufficient technological overlap? And is compatibility of knowledge at the start of the collaboration a precondition for the acquisition of knowledge? Both Lane and Lubatkin (1998) and Quintas and Guy (1995) emphasise the importance of similarity and compatibility of the firms' knowledge for firms to access useful knowledge and to learn from it.
- Is knowledge assimilation dependent on a similar approach to problem solving?

Technology:

- What role does technology play for the assimilation of knowledge between the partners?

- How efficient are the KM systems of the collaborating firms in acquiring knowledge form each other?

Compensations practises:

- Are the compensation practices found in the partnering firms important for the assimilation of knowledge and if so, why? Lane and Lubatkin (1998) find that the similarity of compensation practices is positively associated to inter-organisational learning.

Informal process:

- How important are the informal processes for knowledge assimilation?
- To what extent do you rely on your own networks and search? Why do you do so?

  Do you feel that the collaboration fails to provide you with new knowledge to work on, why/why not?
- Did you experience any problems of assimilating the knowledge throughout the collaboration when developing the drug? What do you consider the most common problems related to the assimilation of new knowledge in a collaboration, and what consequences do these have?

Further interview questions related to transformation of knowledge

- What are the key processes that trigger the transformation of knowledge
- How did the transformation of the knowledge happen? Own yardsticks?
- Do you think transformation of knowledge is more difficult when collaborating with another firms as opposed to relying on your own firm?

Further interview questions related to exploitation of knowledge

General questions:

- How is the new knowledge created through the collaboration being integrated and further exploited in your firm? To what extent would you say collaborations help your firm's innovative capabilities?
- As it can take long time to get drugs approved, what did your firm do with the knowledge it just had exploited while waiting for the approval? I.e. did you suspend the research on this stream of knowledge, or did your firm carry on using it in the same or other streams of research?

Specific questions:

- What would you say were the crucial factors behind the exploitation of the knowledge for this drug?
- Do you see familiarity of the other firm's dominant logics as a necessary condition for a collaboration exploiting the transformed knowledge? Lane and Lubatkin (1998) hold familiarity and exploitation positively related.

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